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(6) VERIFICATION OF SHIPBOARD WASHDOWN COUNTERMEASURE [U],

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FOREWORD

This report presents the preliminary results of one of the projects participating in the military-effect programs of Operation Redwing. Overall information about this and the other military-effect projects can be obtained from WT-1344, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

ABSTRACT

Project 2.10 was conducted to verify the effectiveness of a washdown system as a radiological countermeasure for ships. The evaluations were made possible by the requirement for washdown-equipped ships to be stationed within the region of tactically significant fallout in order to support several projects in the fallout characterization program of Operation Redwing.

To fulfill the instrumentation requirements of Program 2, the Bureau of Ships test ships, YAG-39 and YAG-40, were employed. Washdown effectiveness was measured by a comparison of gamma-radiation field measurements taken in the unwashed control area forward and the washed after portion of each ship.

The test ships participated in five shots and at least one of them was sufficiently contaminated in four of these to make washdown evaluation feasible. Maximum levels of gamma radiation encountered ranged from 266 mr/hr at 11 hours after Shot Flathead to 21.2 r/hr at 4.6 hours after Shot Tewa. The four events provided two general types of contaminant, a solid particulate material from Shots Zuni and Tewa and a salt-water slurry from Shots Flathead and Navajo. The latter contaminant was similar to that encountered from Shots 4 and 5 during Operation Castle.

Total accumulated gamma dose at the time of cessation of fallout was reduced 95 to 97 percent in the case of the slurry material, and 76 to 8[illegible] percent for the dry fallout. Total dose rates were reduced at the end of washdown 85 to 98 and 85 to 95 percent for the slurry and dry fallout types respectively. Removal of the dry material deposited on the ships varied from 74 to 96 percent at the time washdown was secured.

The results from Operation Castle concerning washdown effectiveness against relatively small amounts of salt-water slurry-type fallout are confirmed, and recommendations for further testing are made.

PREFACE

The dependency of Project 2.10 upon the data taken and processed by Project 2.71 will become apparent as the reader progresses through this report. The rapid and thorough decontamination of the test ships between participations accomplished by Projects 2.8 and 2.9 was also necessary for success. The cooperation of these projects in the design and conduct of their respective tasks so as to provide the instrumentation and recovery required for the evaluation of the washdown countermeasure is gratefully acknowledged.

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TABLES

FIGURES

Chapter 1
INTRODUCTION

1.1 OBJECTIVE

The objective of Project 2.10 was primarily to evaluate the effectiveness of the washdown countermeasure under fallout conditions resulting from several Redwing shots, and secondarily, to supplement prior data on washdown.

The results from this project together with the techniques and material studies of Project 2.8 (Reference 2), the proposed standard ship recovery procedures of Project 2.9 (Reference 3), and the ship-shielding determinations of Project 2.71 (Reference 4), were planned to provide basic information leading to the establishment of a shipboard radiological countermeasures-and-decontamination system that could be recommended to the Chief of Naval Operations as part of a Shipboard Nuclear Weapons Defense System.

1.2 BACKGROUND

Laboratory studies and ship trials (References 5, 6 and 7), using fallout simulants, have indicated that a washdown system capable of covering an entire ship's weather surfaces with salt-water spray is operationally feasible, and provides a rapid and effective means of reducing the radiation hazard to personnel during and after a contaminating event.

Based upon the simulant-type feasibility studies, a request was made by the Chief of Naval Operations that the effectiveness of washdown systems be verified under actual contaminating conditions. Consequently, two Liberty Ships (YAG's 39 and 40) were converted to shielded, radio-remote-controlled test vehicles, one being equipped with a washdown system and one without. Washdown evaluations were conducted during Operation Castle (Reference 1) and Operation Wigwam (Reference 8).

A typical result obtained during Castle indicated that the washdown countermeasure reduced an otherwise potential gamma dose of 300 r at 10 hours after burst by 87 to 94 percent and reduced the radiation field gamma dose rate at an exposed location by 90 to 96 percent at the time fallout had ended (Reference 1).

During Wigwam, a deep underwater detonation was experienced by the test ship equipped with washdown. The primary radiation hazard was apparently due to air-borne contaminant which passed near the ship, a situation in which washdown cannot be effective. There was little residual contamination from the washdown water, even though the ship traversed patches of contaminated ocean (Reference 8).

For operation during the Castle tests, the YAG-39 was completely equipped with a washdown system and other candidate countermeasures, whereas the YAG-40 was operated unprotected. Figure 1.1 shows the YAG-40 with a full washdown system in operation (this was installed subsequent to Castle), and Figure 1.2 shows the YAG-39 with the partial washdown system in operation as used on both ships for Operation Redwing.

The ships were operated together during Castle and it was assumed that each would

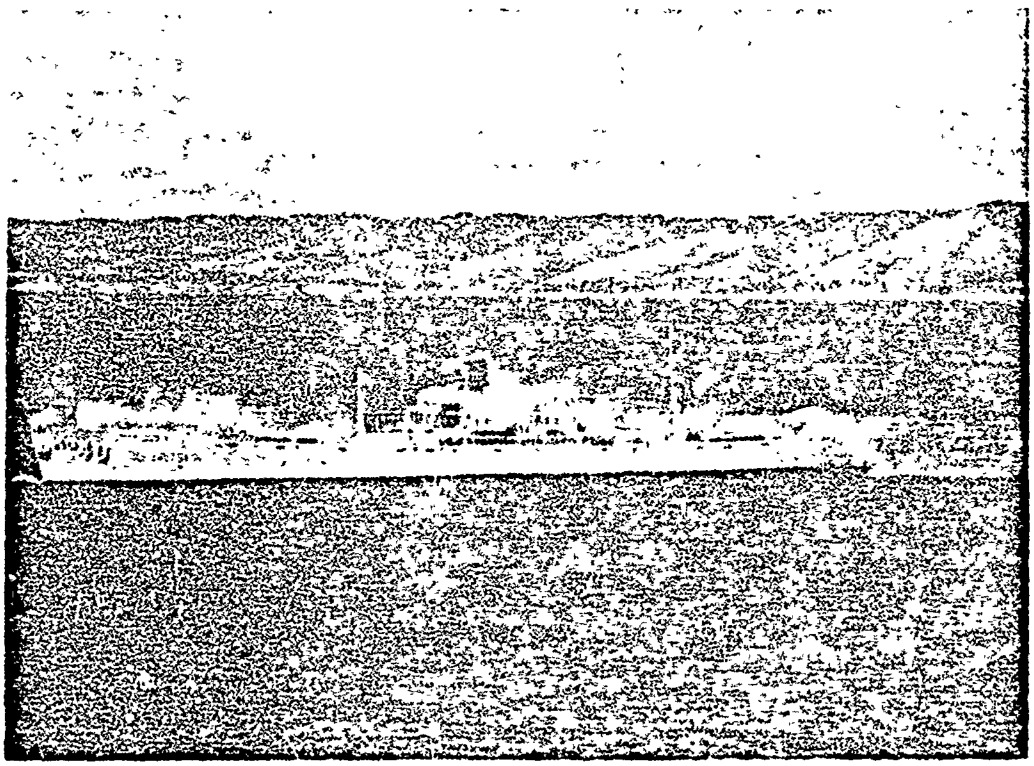


Figure 1.1 YAG-40 under way with full washdown.

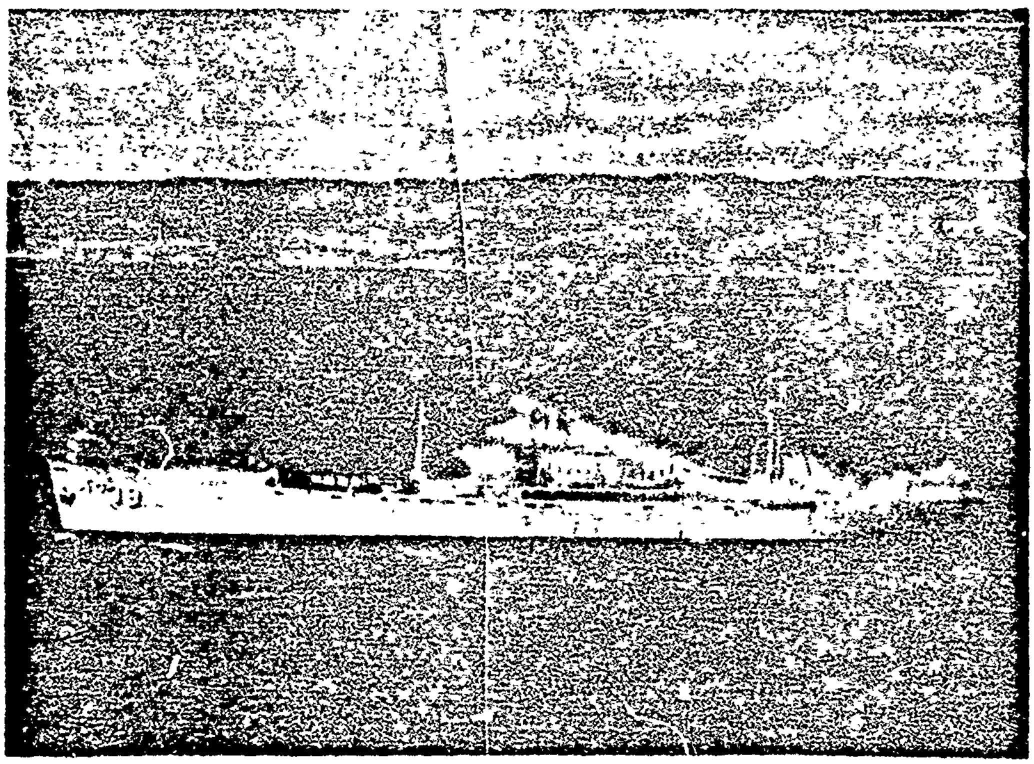
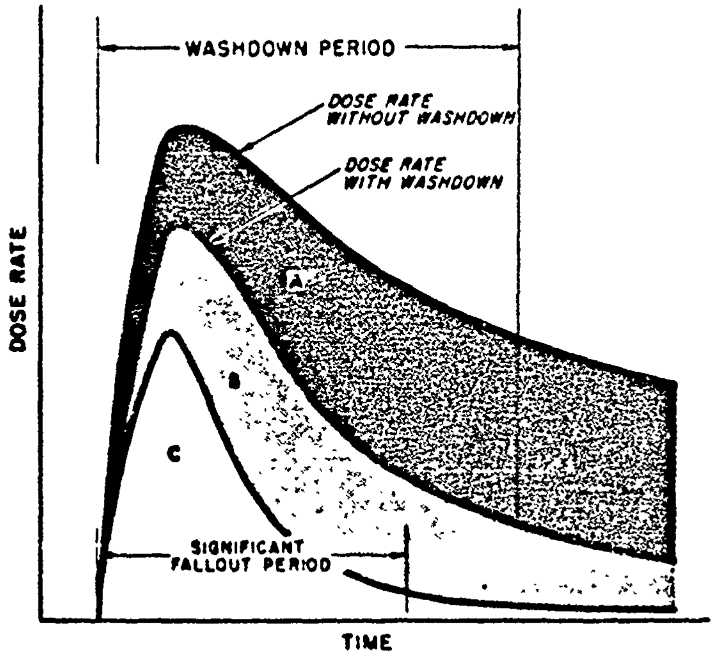


Figure 1.2 YAG-39 under way with after washdown only.

be subjected to the same amount of deposited contaminant. Thus, the washdown effectiveness was to be obtained by direct comparison of the average gamma doses and dose rates measured on the same areas of each ship. In spite of the fact that the ships maintained station and were never more than 1,500 yards apart during fallout, the gamma intensity-time data indicated that the ships were subjected to different degrees of contamination. Before direct comparison could be accomplished, the gamma history of



A Dose from contaminant deposited, but removed (saved) by washdown

B Dose from deposited contaminant not removed by washdown

C Dose contributed by air- and water-borne contaminant

Figure 1.3 Breakdown of shipboard deck dose rates during a contaminating event.

one ship had to be arbitrarily adjusted to account for probable differences in amounts of contaminant deposited. To eliminate this variable, it was recommended that washed and unwashed sections on the same ship be compared in any future tests (Reference 1).

During Redwing, the forward sections of YAG-39 and YAG-40 were kept clear of the washdown in order to assure that no moisture would be carried into the fallout collection and decontamination study areas (see Figure 1.2). Thus, the washdown test conditions recommended in the Castle Report (Reference 1) were provided and washdown evaluation by comparison of radiation measurements taken in washed and unwashed areas on each ship was possible.

1.3 THEORY

During a contaminating event aboard ship, the gamma radiation field on deck is the sum of the radiations from the contaminant deposited on the weather surfaces, from radioactive particles in the air surrounding the ship, and from contaminant in the water nearby. The contribution from each of these sources to the total radiation field at any

particular point will depend on their relative magnitudes and on the intervening distances and structures.

Figure 1.3 shows how deck doses and dose rates can be suppressed by washdown removal of part of the contaminant deposited on the weather surfaces both during and after the contaminating event.

Washdown effectiveness is defined as the percentage reduction of gamma radiation hazard aboard ship attributable to washdown.

This effectiveness may be measured in four ways, each of them significant: (1) Percentage reduction of total dose, E_{TD}; (2) Percentage reduction of dose rate from all sources (total dose rate), E_{TR}; (3) Percentage reduction of dose from deposited contaminant, E_{DD}; and (4) Percentage reduction of dose rate from deposited contaminant, E_{DR}. Assuming no difference in decay rates in the washed and unwashed areas, no portion of the washed area is left unwashed, and no contaminant removal phenomena such as rain occurs, these measures of effectiveness may be expressed as follows:

$$E_{TD}(t) = 100\left[1 - \frac{D_w}{D_u}\right] \tag{1.1}$$

$$E_{TR}(t) = 100\left[1 - \frac{R_w}{R_u}\right] \tag{1.2}$$

$$E_{DD}(t) = 100\left[1 - (D_w - a)/(D_u - a)\right] \tag{1.3}$$

$$E_{DR}(t) = 100\left[1 - (R_w - A)/(R_u - A)\right] \tag{1.4}$$

Where: D_w = total gamma dose accumulated within washdown area up to time t

D_u = total gamma dose accumulated within unwashed control area up to time t

t = time in hours after detonation

R_w = gamma dose rate in washed area at time t

R_u = gamma dose rate in unwashed control area at time t

a = gamma dose contributed by the air- and water-borne contaminant up to time t

A = gamma dose rate at time t contributed by the air- and water-borne contaminant

From Figure 1.3 and Equations 1.1 through 1.4, it can be seen that at a given time during the period of significant fallout, E_{DD} and E_{DR} will be greater, respectively, than E_{TD} and E_{TR} because of the contribution from air- and water-borne contaminant which washdown cannot affect. However, after significant fallout has ceased and the ship is no longer in contaminated water, E_{DR} and E_{TR} become equal, but E_{DD} will remain greater than E_{TD}.

During a contaminating event, the values of washdown effectiveness will vary, depending on a number of factors such as rate of fallout arrival, the portion of the radiation field contributed by air- and water-borne contaminant, the promptness with which the washdown

is activated, the manner in which the ship is maneuvered relative to the surface wind and so on.

As the rate of fallout arrival decreases, washdown effectiveness can be expected to increase and then level off as the amount of material being removed by the washdown water becomes less and less.

For the purpose of washdown evaluation, the times of major interest during the contaminating event are (1) the time of maximum fallout arrival rate (assumed to be the time of maximum dose rate from airborne contaminant) and (2) the time of washdown cessation. The significance of the four measures of washdown effectiveness at these times is summarized in Table 1.1.

TABLE 1.1 SIGNIFICANCE OF WASHDOWN EFFECTIVENESS

	Time of Interest: Maximum Fallout Arrival Rate (Peak Dose Rate from Air-borne Contaminant)	Time of Interest: End of Washdown (Assume No More Significant Fallout)
E_{TD} Pct reduction, total dose		Measure of total dose saved by washdown
E_{TR} Pct reduction, dose rate, all sources		Measure of future dose saved
E_{DD} Pct reduction, deposit dose		Measure of washdown ability to remove contaminant
E_{DR} Pct reduction, deposit dose rate	Measure of rate of contaminant removal by washdown with respect to maximum rate of arrival	Measure of future dose saved

Chapter 2

PROCEDURE

2.1 OPERATIONS

Washdown evaluations were planned for Shots Cherokee, Zuni, Flathead, Navajo, and Tewa.

Operational control of the YAG's was exercised aboard the Naval Task Group's Command Ship, USS Estes (AGC-12), from a central control and communications station. The ships were positioned according to the requirement of Project 2.63 (Reference 9) to gather specific data and information concerning the nature and extent of the fallout from each of the shot participations. Although this requirement did not allow placement of the YAG's for optimum washdown evaluation conditions during all shots, it did provide the opportunity to obtain comparative information among fairly representative types of weapon employment, both on water and land surfaces.

Based upon fallout predictions, the YAG's were positioned at distances varying 25 to 80 miles from surface zero. Upon arrival on station, the ships were maneuvered to correct for any alterations in the predicted fallout path brought about by variations in the observed upper wind structure. Once either ship commenced to receive fallout, the washdown system over the after-half of the ship was activated, conning was transferred from the bridge to the shielded control room and the ship was maneuvered to maintain a relatively fixed position with respect to surface zero. The washdown system was secured when it became apparent from observed dose rate decay that significant fallout had ceased and that no further appreciable removal of contaminant was being achieved. When ordered by the control station aboard the AGC-12, the ships departed station, and delivered fallout samples to Bikini, and then proceeded to Eniwetok. Upon arrival at Eniwetok, radiological decontamination and recovery operations were commenced. When radiological surveys and special decontamination studies (References 2 and 3) were completed, the ships were readied for the next participation.

Details of the ships' facilities may be found in Reference 10.

2.2 INSTRUMENTATION AND DATA REQUIREMENTS

2.2.1 Washdown System. The washdown water on both ships was supplied from inlets approximately 20 feet below the water line by three 1,000-gpm pumps, discharging approximately 2,000 gpm at 100 psi.

The nozzles were located to provide complete weather deck coverage on the YAG-39 for Operation Castle, and minor changes were made for the Wigwam and Redwing participations. Figure 2.1 shows the nozzle positions on the washed portion of the ship as located for Operation Redwing.

The system aboard the YAG-40 was designed and installed for the Redwing tests and reflects the experience gained with the YAG-39 system. Effectively, the only difference was the arrangement of the nozzles which is shown in Figure 2.2.

2.2.2 Radiation Detection. Certain stations of the gamma-radiation-detection-and-recording system (called GITR, gamma-intensity-time recorder) installed aboard the

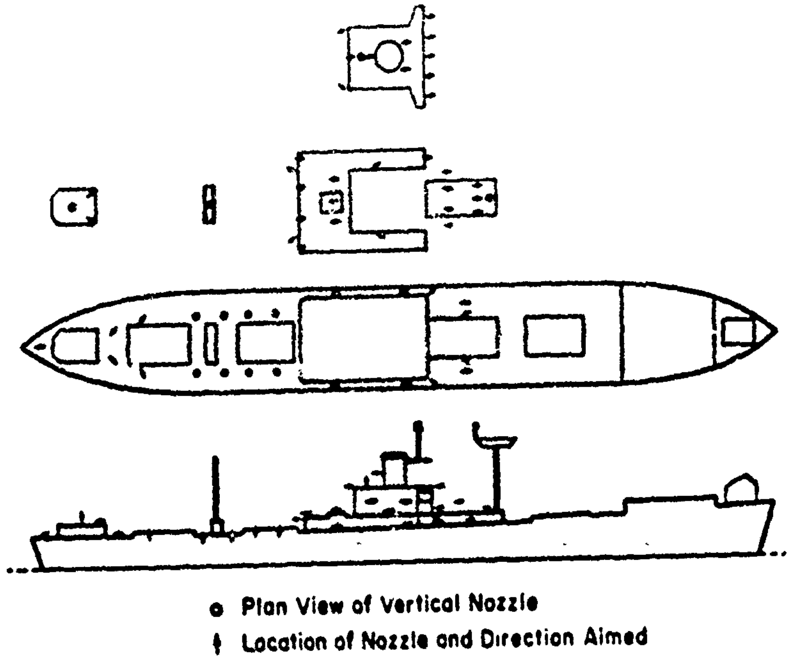


Figure 2.1 Location of washdown nozzles on YAG-39 used on Operation Redwing.

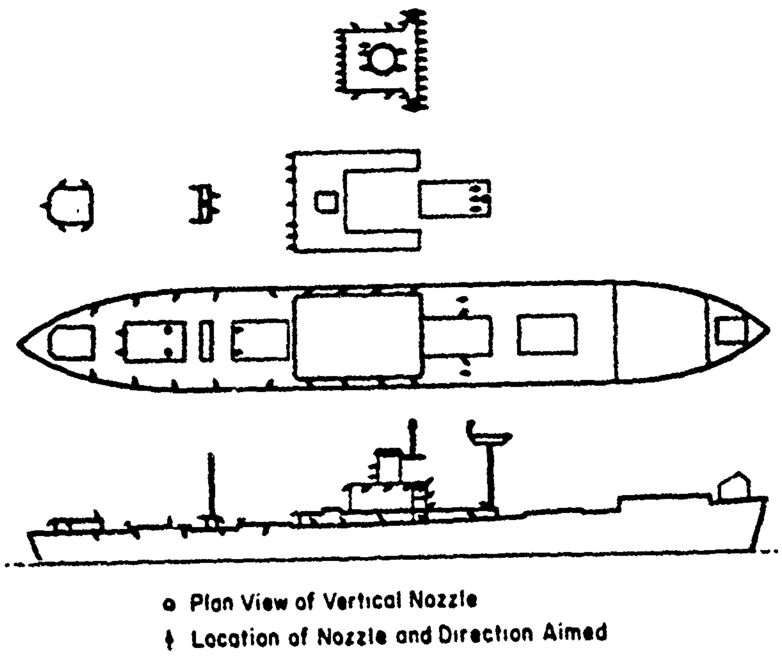


Figure 2.2 Location of washdown nozzles on YAG-40 used on Operation Redwing.

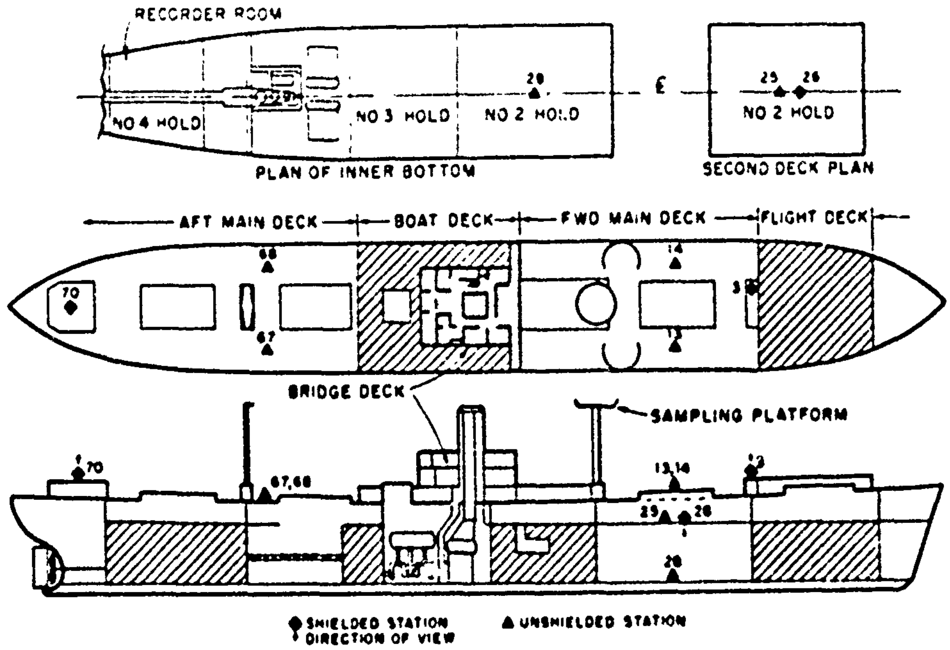


Figure 2.3 Location of gamma detector stations on the YAG's.

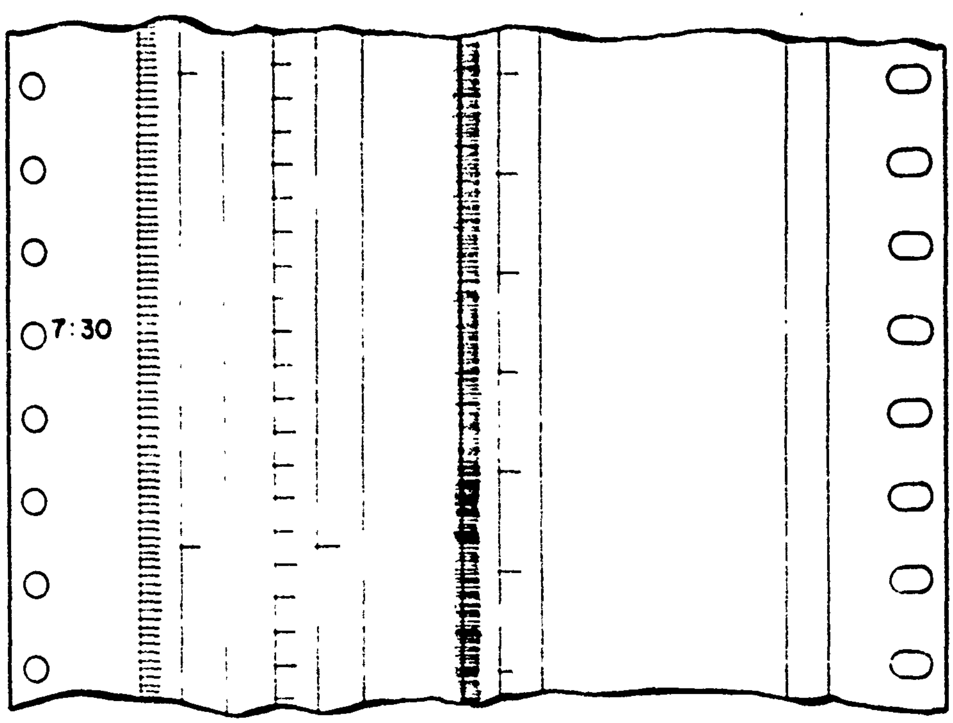


Figure 2.4 Typical GITR tape.

YAG's for Operation Castle, were activated by Project 2.71. The instrument station locations and identifying numbers of those stations used by Project 2.10 are shown in Figure 2.3.

Each station consisted of a group of 4 detectors positioned 3 feet above the deck surface and capable of measuring dose rates in the range of 1.5 mr/hr to 3,600 r/hr. The detectors were air-filled ion chambers having a flat energy response down to less than 100 kev. The ionization current discharged a capacitor so sized that when a given gamma-dose increment was received, the associated electrometry activated a relay which in turn sent a pulse to a recorder and also recharged the capacitor. The data were recorded as dose increments on a constant speed tape (Figure 2.4).

A more-complete description of the detection-and-recording system may be found in Chapter 8 of the Project 6.4 Operation Castle Final Report (Reference 1) and Redwing Project 2.71 Interim Test Report (Reference 4).

Gamma-dose and dose-rate information as a function of time from Stations 13 and 14 in the unwashed areas and from Stations 67 and 68 in the washed portions of both ships were required from Project 2.71.

The contribution to deck dose rates, as measured by Stations 13 and 14, 67 and 68, of radiations from air- and water-borne contaminants was estimated by Project 2.71 personnel from measurements taken by detector Stations 70 and 3 (air-borne contaminant) and 25, 26, and 28 (water-borne activity). See Figure 2.3.

The probable instrument error of the reduced data regarding dose and dose rate is plus or minus fifteen percent. The error in the air- and water-borne contributions varies from plus or minus 25 to 50 percent. This large error is due to approximations necessary in the estimating technique of adjusting recorded values to meaningful ones. For a description of the data reduction techniques and the assignment of errors, see Reference 4.

2.2.3 Time of Fallout Cessation. The actual time of fallout cessation was very difficult, if not impossible, to measure. For the purposes of this report, the end of significant fallout for each participation was taken as the reported average of the times when 99 percent of the total activity in each of the Project 2.63 incremental collectors had arrived.

2.2.4 Wind Data Requirement. Relative wind speed and direction data were provided in reduced form as a function of time from a Bendix Fries wind speed and direction recording set which was installed aboard each ship.

2.2.5 Operational Data. A 2.10 project representative was aboard each ship for each participation. All operational data such as times of washdown activation and shutdown and a record of ships' maneuvers were logged.

Chapter 3
RESULTS

3.1 OPERATIONS

3.1.1 Insignificant Shot Participations. Since neither of the test ships encountered fallout worthy of mention during the sorties made for Shot Cherokee, no washdown evaluation was possible.

The YAG-39, during the Zuni and Flathead operations, and the YAG-40, during Navajo, received so little fallout as to render valueless any washdown evaluations based on data from these events.

The remainder of the planned participations produced the data which follows.

3.1.2 Ships' Operations, General. Tables 3.1, 3.3, 3.5, 3.7, and 3.9 present a summary of ship operational data for productive sorties.

The plan for operational control of the test ships from USS Estes worked satisfactorily.

Station keeping presented some difficulty. It can be seen in the tables under the heading, "Course and Maneuver" that sometimes a straight course at slow speed was accomplished and at other times a figure-eight maneuver was used. This apparent inconsistency was caused by the fact that during Shots Navajo and Tewa, the wind and sea conditions were such that at minimum speed to maintain steerageway, the rate of advance of the ships exceeded the limits required by Project 2.63. The figure eight perpendicular to the wind, although not the ideal condition for washdown evaluation, was decided upon as a compromise.

No instrument failures occurred.

3.2 WATER-BORNE CONTAMINANT CONTRIBUTION

The data from detector Stations 25, 26 and 28 showed that the contribution to the radiation field on deck from water-borne contaminants, in all cases, was less than one percent of the total (Reference 4). Therefore, in computing the effectiveness of the washdown countermeasure based on removal of deposited material, only the contribution from airborne contaminant is subtracted from the total radiation measurements (Equations 1.3 and 1.4).

3.3 ESTIMATES OF THE CONTRIBUTION FROM AIR-BORNE CONTAMINANT

As was indicated in Chapter 2, an effort was made to obtain the air-borne particle contribution to the deck radiation field in both the washed and unwashed areas during each participation. This was actually possible in only one case, the YAG-40's Tewa experience. The lack of one or the other of these air-contribution estimates is not particularly serious, however, since in the instance where both are available, they are not significantly different, particularly at the higher values where their influence is most felt. Where only one of these estimates is available and it is applied in both areas, wider (± 50 percent) limits of accuracy are assigned than in the case where one estimate serves as a check

on the other (± 10 percent at higher levels, ± 25 percent over an intermediate range and ± 50 percent for the lowest values). (See Reference 4.)

During Shots Flathead and Navajo, unfortunately, the intensity of the contribution from the air to the gamma field on deck was so low as to make estimation impractical. Therefore, for these shots, no measure of washdown effectiveness based on removal of deposited material is possible.

3.4 WASHDOWN EFFECTIVENESS AGAINST SLURRY-TYPE CONTAMINANT

Water-surface bursts Flathead and Navajo produced fallout consisting of high-salt-content liquid droplets, approximately 100 microns in diameter containing radioactive

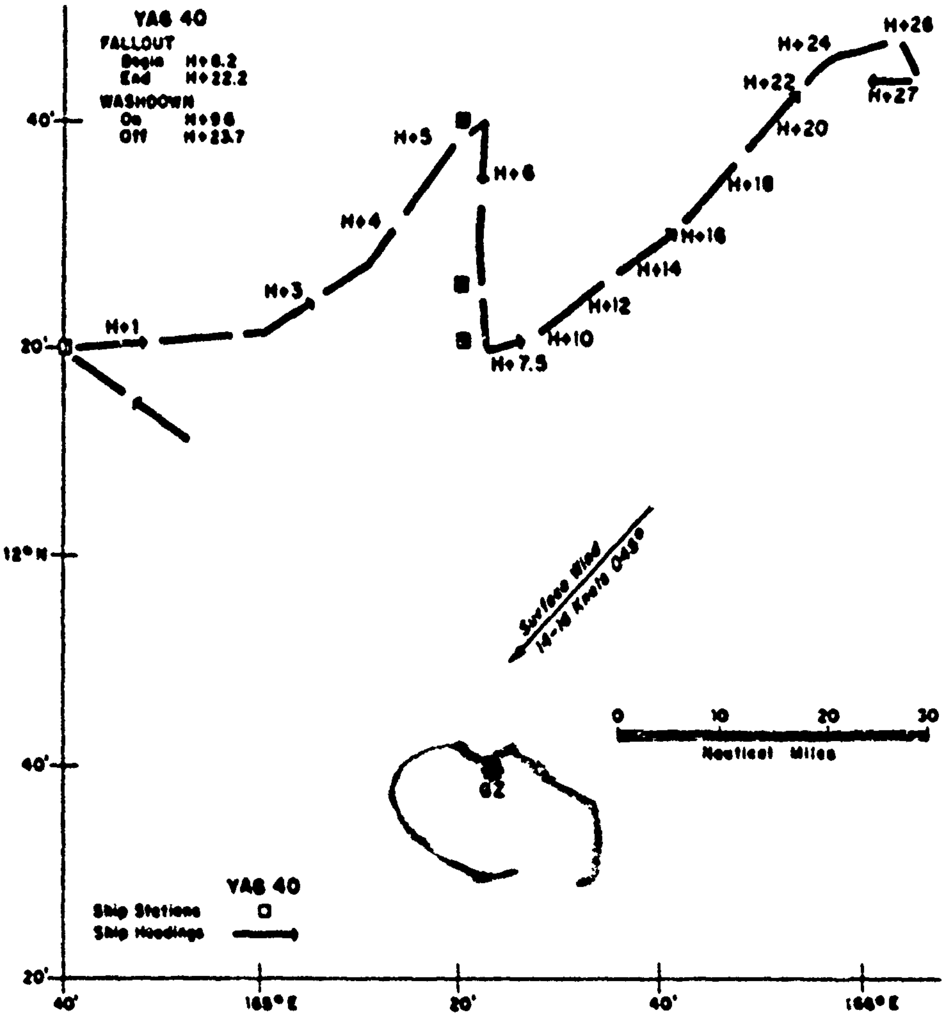


Figure 3.1 Track made by YAG-40 during Shot Flathead participation.

particles less than 30 microns in size. This type contaminant is hereafter referred to as a slurry.

3.4.1 Shot Flathead. Operational Data. Table 3.1 and Figure 3.1 indicate the operational data for YAG-40 in connection with Shot Flathead. Surface winds are pre-

sented that their effect on washdown can be evaluated. Fallout patterns of course depend on the winds aloft.

Radiation and Washdown Effectiveness Data. Figures 3.2 and 3.3 present the average dose rates and doses versus time from the washed and unwashed areas (from Stations 13 and 14, 67 and 68, respectively).

Two interesting features of the dose-rate curves in Figure 3.2 are: (1) the length of time, some 9 hours, from the start of fallout to the peak gamma deck dose rate, indicating a gradual arrival of fallout over a relatively long period, and (2) the sharp drop off of the dose rate in the washed area immediately after the washdown was activated.

The variation of washdown effectiveness based on the reduction of total dose rate and total dose with the limits of uncertainty denoted by the shaded areas is depicted in Figures

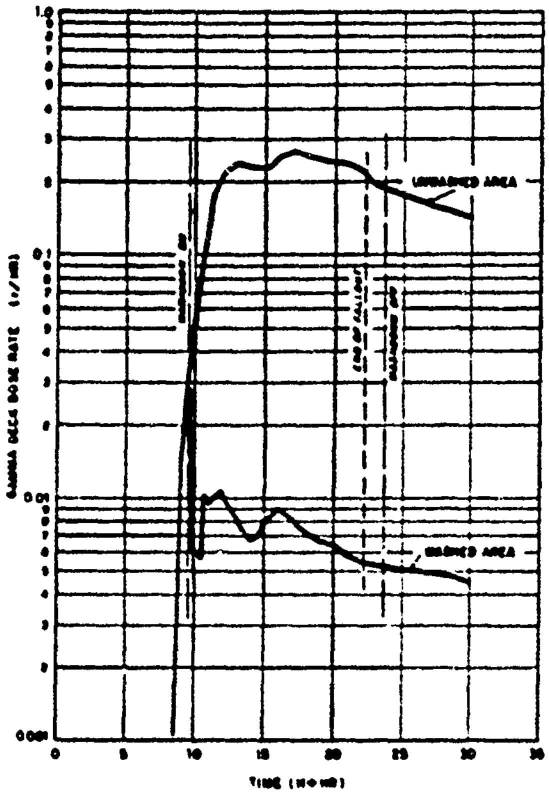


Figure 3.2 Average gamma deck dose rates from washed and unwashed areas versus time after Shot Flathead on YAG-40.

3.4 and 3.5, respectively. See Appendix for sample calculations. The effect of the abrupt changes in dose rates is not shown on the accumulated dose curves because of the log scale and degree of uncertainty in the basic data.

Table 3.2 gives the particularly significant washdown effectiveness values as outlined in Table 1.1.

3.4.2 Shot Navajo. Operational Data. Operational data for the YAG-39 during the Navajo sortie are presented in Table 3.3 and Figure 3.6.

Station keeping was done by maneuvering the ship in a figure eight with the long axis perpendicular to the surface wind direction, as the wind and seas were light.

TABLE 3.1 YAG-40 OPERATIONAL DATA FOR SHOT FLATHEAD

Type of fallout	Salt-water slurry
Distance from GZ	40 miles north
Surface wind velocity	14 to 16 knots 045°
Rain during washdown	None
Course and maneuver	H + 7.5 to H + 26, 045° at 3 knots
Time of:	
First rise in background	H + [illegible].6
Fallout start	H + 8.2
Peak air dose rate	—
Peak deck dose rate	H + 17.0
End of fallout	H + 22.2
Washdown on	H + 9.6
Washdown off	H + 23.7
Peak mean dose rate:	
Washed area	0.011 r/hr
Unwashed area	0.266 r/hr
Mean total dose at end of washdown:	
Washed area	0.126 r
Unwashed area	2.04 r
Time washdown continued after fallout cessation	1.5 hr

TABLE 3.2 SIGNIFICANT WASHDOWN EFFECTIVENESS (PERCENT), SHOT FLATHEAD AT END OF WASHDOWN (H + 23.7)

	Lower Limit	Observed	Upper Limit
E_{TD}	94.5	96	97
E_{TR}	96	97	98

TABLE 3.3 YAG-39 OPERATIONAL DATA FOR SHOT NAVAJO

Type of contaminant	Salt-water slurry
Distance from GZ	22 miles north
Surface wind velocity	8 knots 090°
Rain during washdown	None
Course and maneuver	H + 1 to H + 18, figure eight perpendicular to the wind
Time of:	
First rise in background	H + 2.0
Fallout start	H + 2.4
Peak air dose rate	—
Peak deck dose rate	H + 6.0
End of fallout	H + 13.4
Washdown on	H + 2.3
Washdown off	H + 8.1
Washdown on	H + 8.6
Washdown off	H + 9.4
Peak mean dose rate:	
Washed area	0.177 r/hr
Unwashed area	1.40 r/hr
Mean total dose at end of washdown:	
Washed area	0.721 r
Unwashed area	5.48 r
Time fallout continued after washdown was secured	4.0 hr

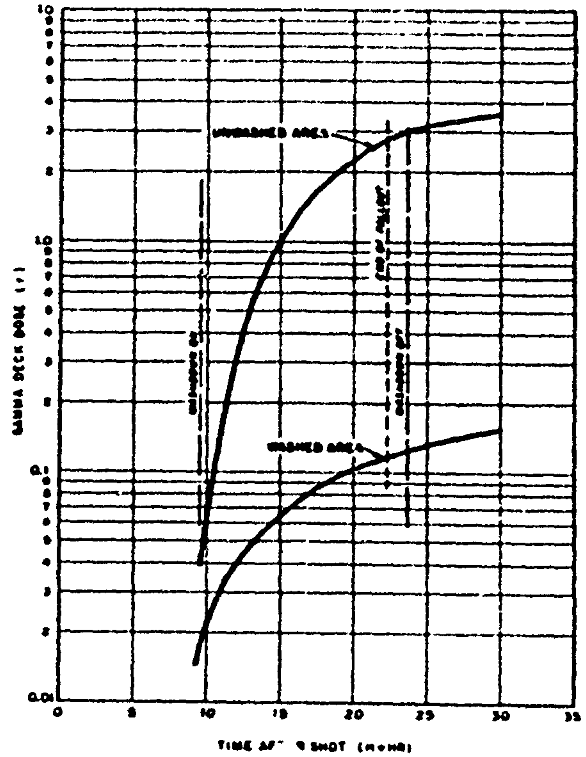


Figure 3.3 Average accumulated gamma deck doses from washed and unwashed areas versus time after Shot Flathead on YAG-40.

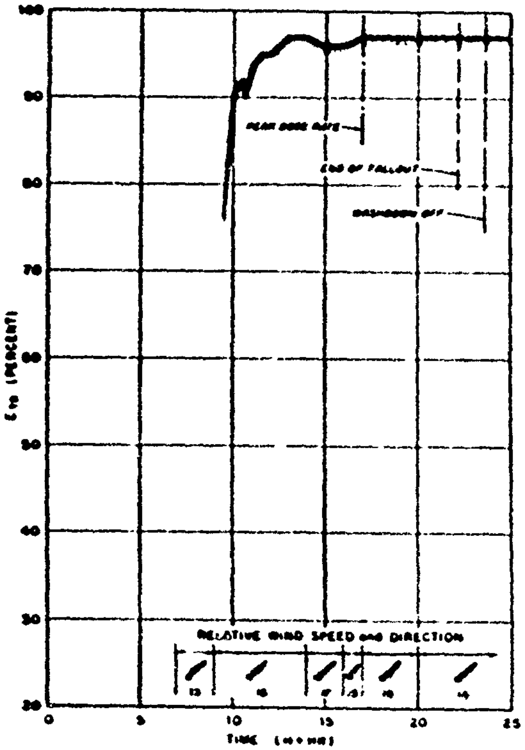


Figure 3.4 Washdown effectiveness based on reduction of dose rate versus time after Shot Flathead on YAG-40. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings, and arrows indicate relative wind direction. Wind speeds are in knots.

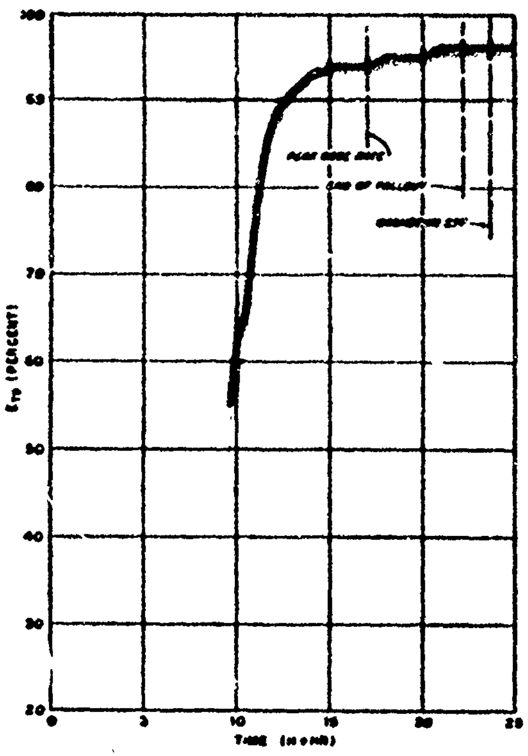


Figure 3.5 Washdown effectiveness based on reduction of total dose versus time after Shot Flathead on YAG-40. Shaded area indicates estimate of uncertainty.

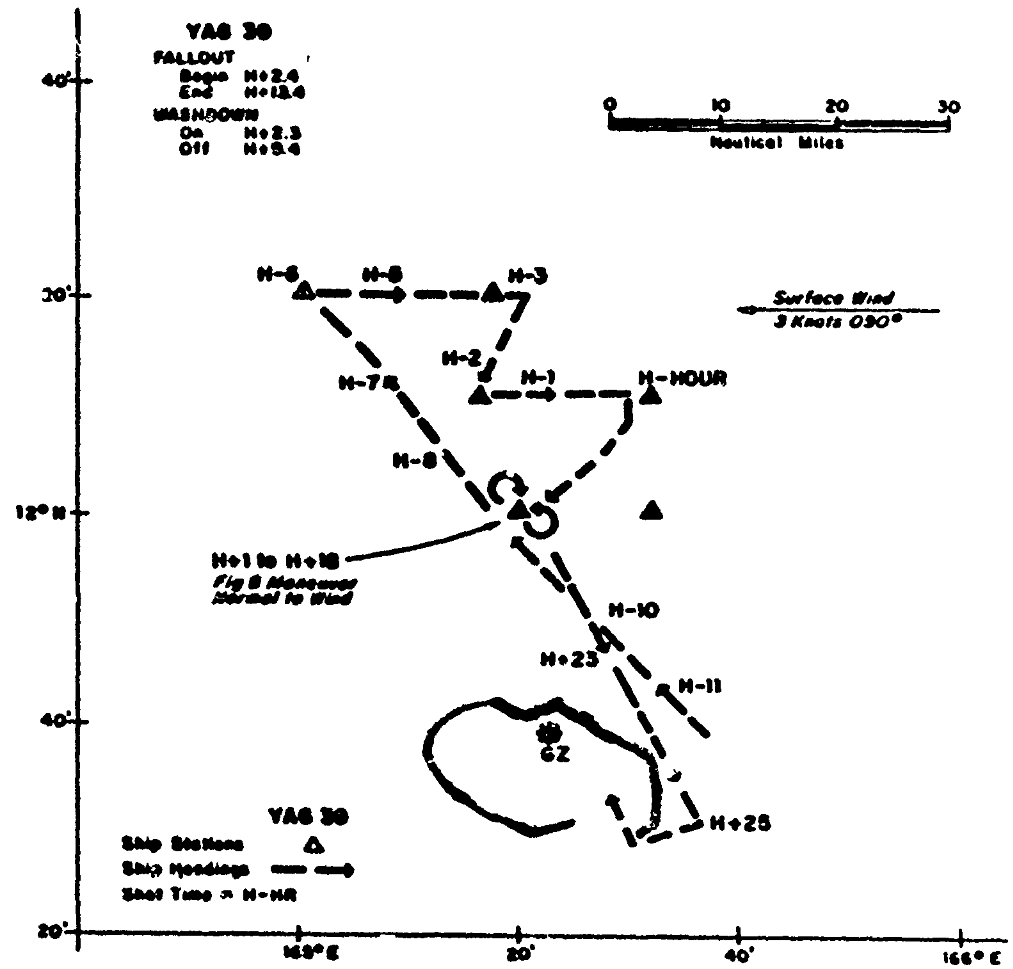


Figure 3.6 Track made by YAG-39 during Shot Navajo participation.

Washdown was operated intermittently since it was necessary for personnel from other projects to be on deck, and it was finally secured 4 hours before the fallout ended.

Radiation and Washdown Effectiveness Data. The average gamma washed and unwashed deck dose rates and doses versus time are given in Figures 3.7 and 3.8.

The steep drop in dose rates at H + 15.5 was due to a severe rainstorm after washdown was secured and all significant fallout had ceased. This time was beyond the area of immediate interest, but knowledge of the effect of rain as a radiological countermeasure could be of use to ships without washdown.

Figures 3.9 and 3.10 picture the variation of effectiveness based on reduction of total dose rate and total dose.

The drop in effectiveness based on reduction of total dose rate, E_{TR} (Figure 3.9) at H + 4 is due to a faster rate of rise of dose rate in the washed area than in the unwashed area between H + 3 and H + 4.

Since the washdown was secured before significant fallout had ceased (it was difficult for personnel aboard the ships to determine the time of fallout cessation), there is a drop in washdown effectiveness (E_{TR}) after washdown was stopped.

Table 3.4 gives the significant values of E_{TR} and E_{TD}.

3.5 WASHDOWN EFFECTIVENESS AGAINST PARTICULATE TYPE CONTAMINANT

Shot Zuni, a land surface burst, and Shot Tewa, a water surface detonation in shallow water produced particulate fallout of radioactive particles in coral residue (Reference 9). See Figures 3.11 through 3.14. Shot Tewa particles were generally smaller than those from Shot Zuni. Although the highest radiation levels of the investigation were obtained from these two shots, this type fallout is judged to be atypical of that to which naval vessels at sea are likely to be exposed.

3.5.1 Shot Zuni. Operational Information. Table 3.5 and Figure 3.15 summarize the operational information for this shot.

It should be noted that the YAG-40 encountered rain squalls during the washdown period which washed deposited material from the control area, thereafter reducing the measured washdown effectiveness.

From H + 3.5 to H + 6 hours, or for the first 2½ hours of the washdown period, the ship was on a course such that the relative wind was on the starboard quarter, a condition not conducive to effective washdown, the system of nozzles being designed for optimum water distribution with the wind on the bow.

Radiation and Washdown Effectiveness Data. Figures 3.16 and 3.17 present the gamma deck dose rates and doses versus time, of the estimated contribution from air-borne contaminant in the washed area (from Station 70), the average total radiation measurements from the washed area (Station 67 and 68) and from the unwashed control area (Stations 13 and 14).

Use of the data from Station 3 in the unwashed area for estimation of the contribution from air-borne contaminants was prevented by the rain storms which occurred at H + 7 and H + 8 hours (Reference 4).

Two points of interest on these dose and dose-rate curves are: (1) the rise in dose rate in the washed area at the time washdown was secured, and (2) the near agreement between the time of the end of fallout marked on the dose curves (from Project 2.63 collectors) and the apparent beginning of the constant portion of the air-contribution dose-estimate curve.

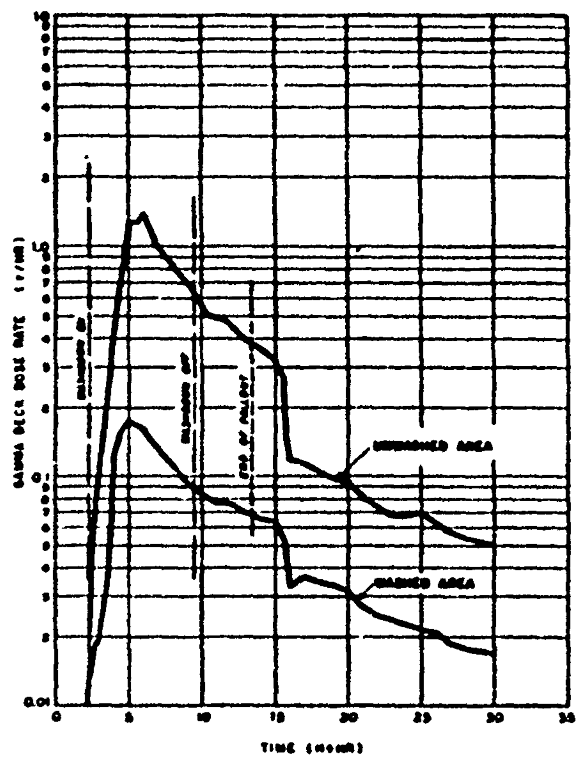


Figure 3.7 Average gamma deck dose rates from washed and unwashed areas versus time after Shot Navajo on YAG-39.

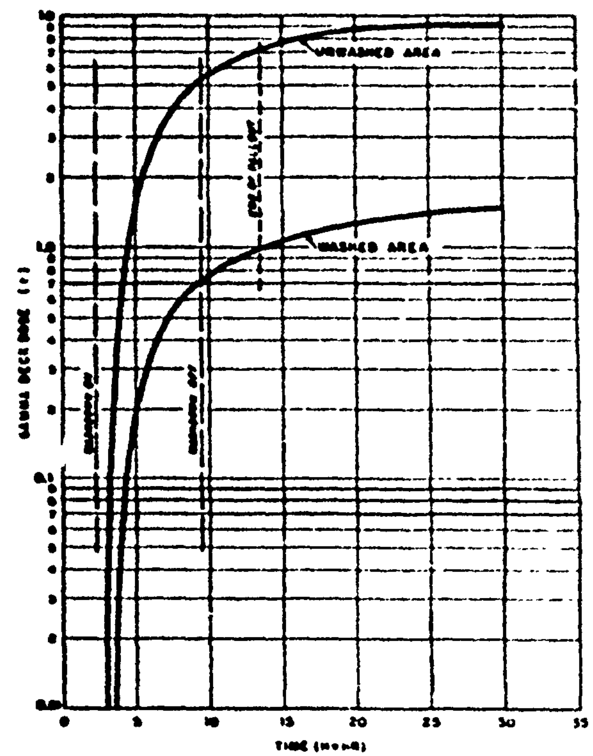


Figure 3.8 Average accumulated gamma deck doses from washed and unwashed areas versus time after Shot Navajo on YAG-39.

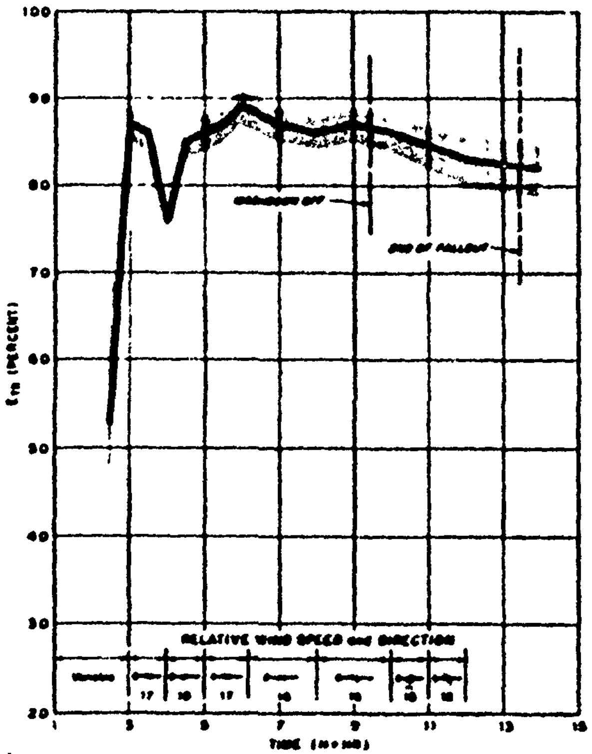


Figure 3.9 Washdown effectiveness based on reduction of total dose rate versus time after Shot Navajo on YAG-39. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

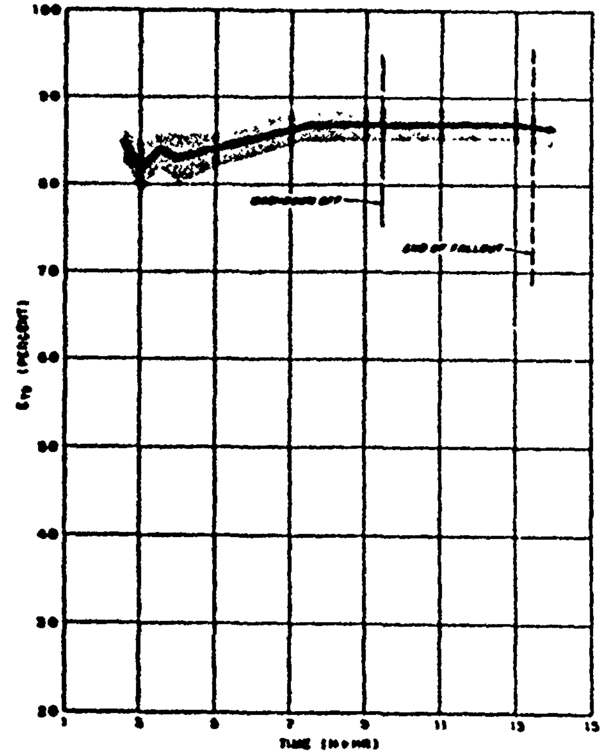


Figure 3.10 Washdown effectiveness based on reduction of total dose versus time after Shot Navajo on YAG-39. Shaded area indicates estimate of uncertainty.

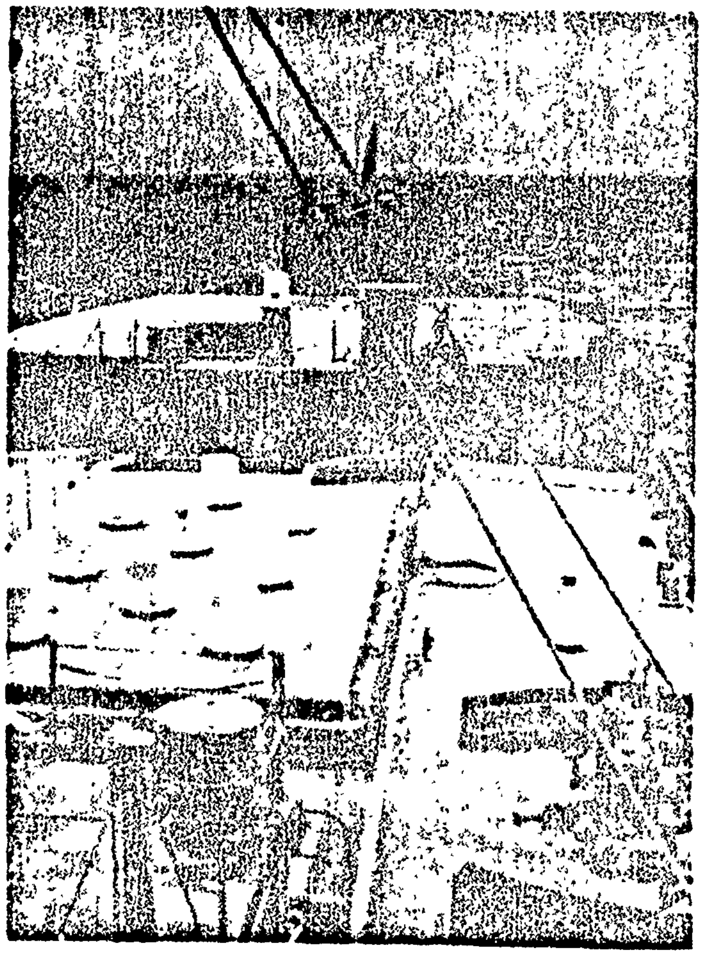


Figure 3.11 Fallout from Shot Zuni on the unwashed area of YAG-40.

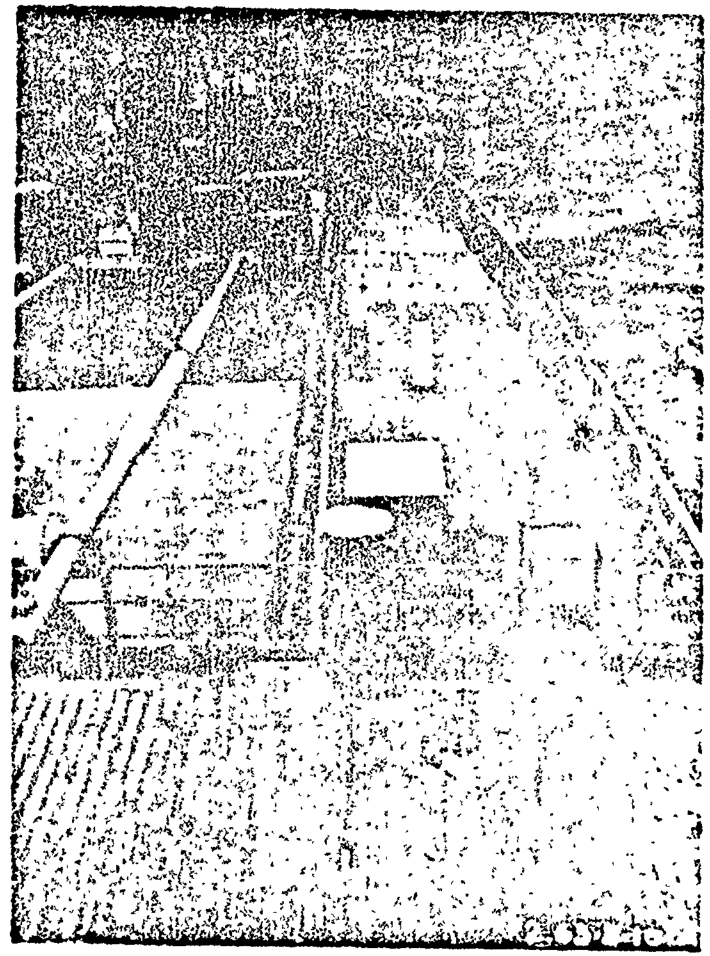


Figure 3.12 Shot Zuni fallout on the washed area of YAG-40. Light area aft is due to different paint color.

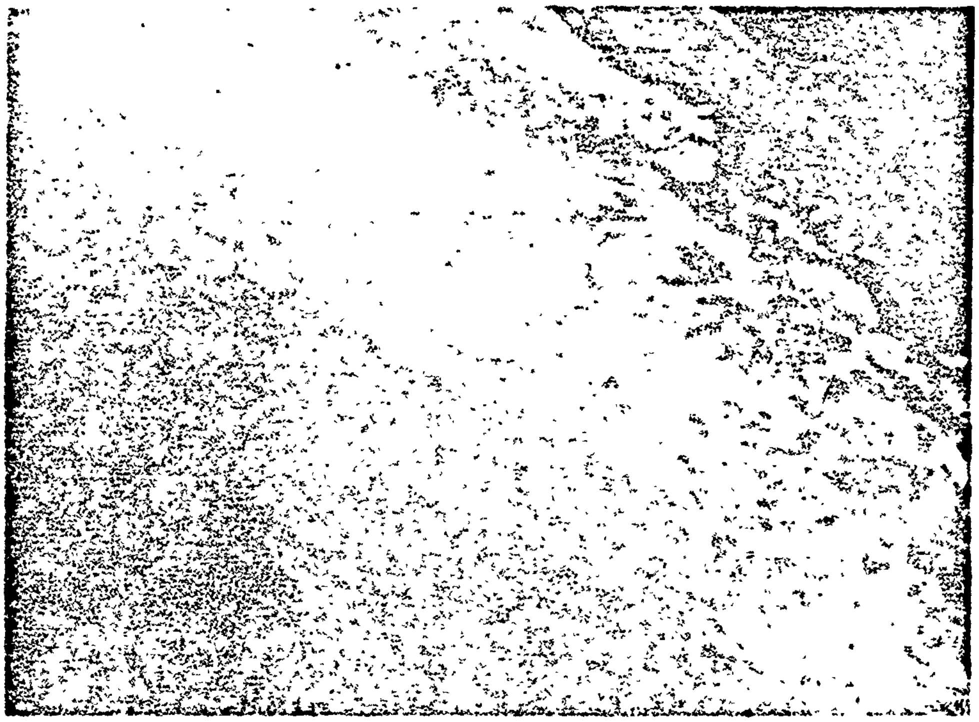


Figure 3.13 Shot Tewa fallout on unwashed area of YAG-39.

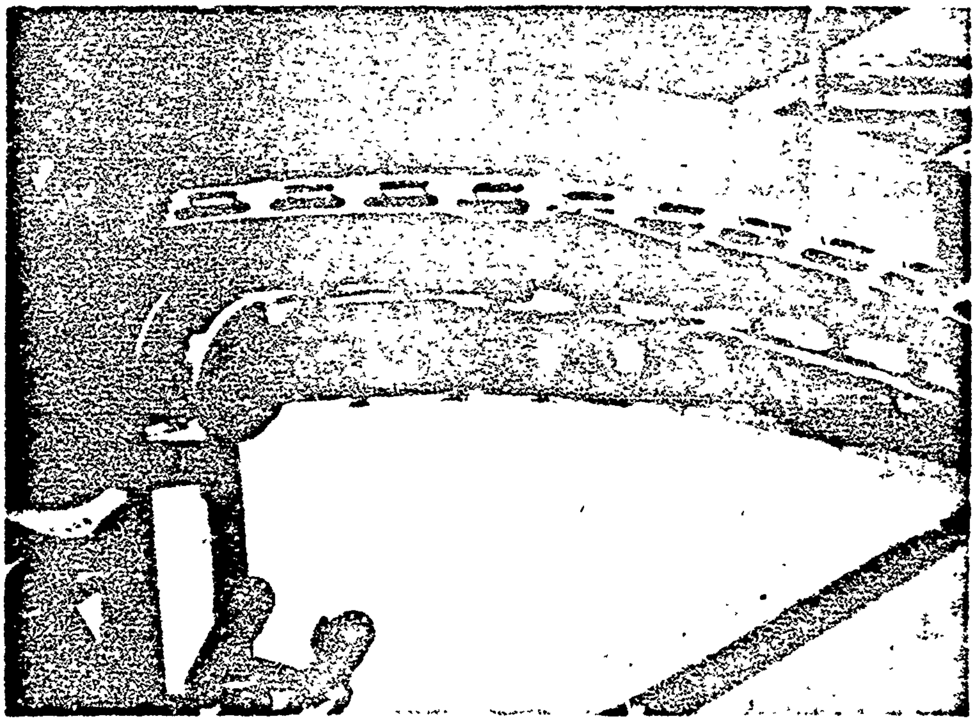


Figure 3.14 Unwashed portion of YAG-39 with fallout from Shot Tewa in evidence.

Figures 3.18 through 3.21 show the variation of the four measures of washdown effectiveness (E_{TR}, E_{TD}, E_{DR}, and E_{DD}, Equations 1.1 through 1.4) with time. The upper and lower limits of uncertainty (shaded areas) are presented as determined by application of the plus or minus 15 percent accuracy of the total dose and dose-rate measurements and

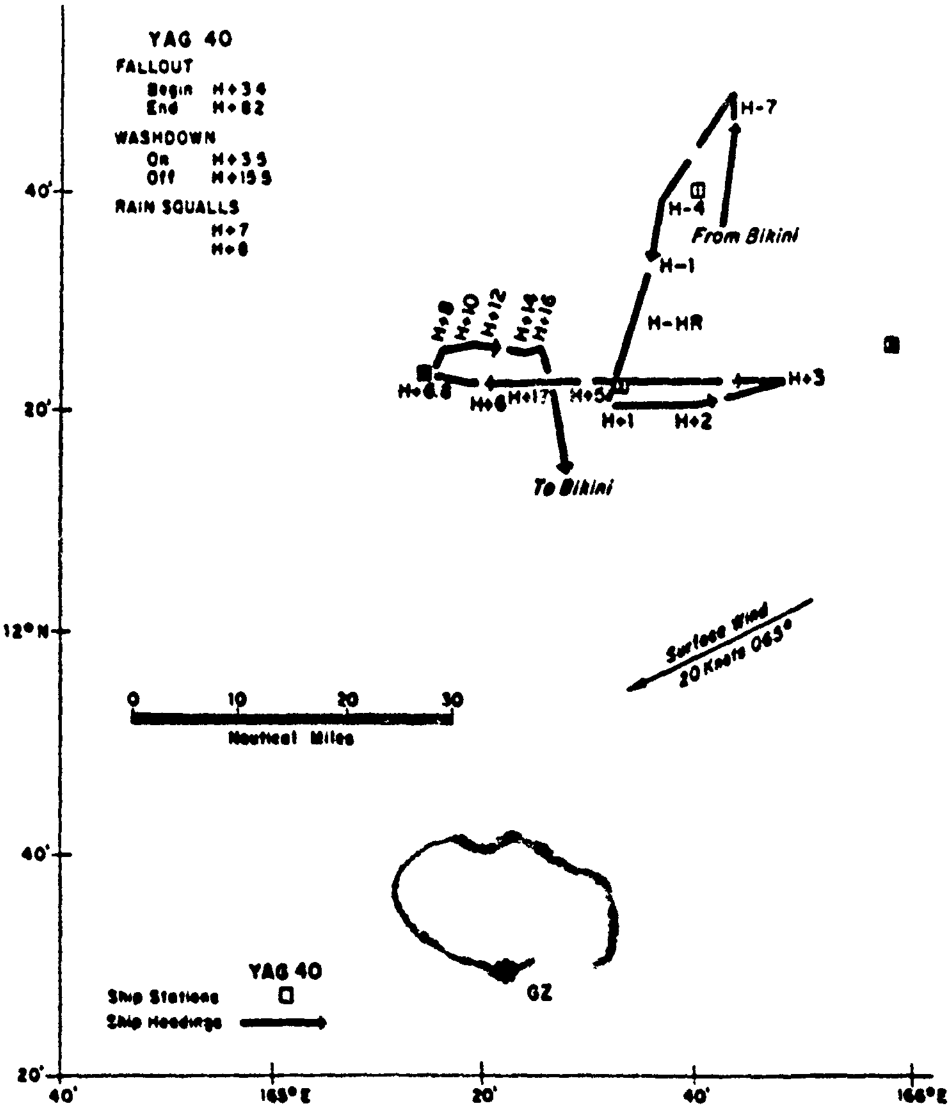


Figure 3.15 Track made by YAG-40 during Shot Zuni participation.

the plus or minus 50 percent accuracy of the air-contribution estimate. See Appendix for sample calculation.

The relative wind speed and direction as it varied with time is indicated on the dose rate reduction graphs (Figures 3.18 and 3.20).

The particular significant values from the curves, as described in Table 1.1, are summarized in Table 3.6.

The decrease in effectiveness based on reduction in dose rate (Figures 3.18 and 3.20) where E_{TR} drops from 85.5 to 79 and E_{DR} from 85 to 79, after washdown was secured, is due to the dose rate increase in the washed area at the same time (Figure 3.16).

TABLE 3.4 SIGNIFICANT WASHDOWN EFFECTIVENESS (PERCENT), SHOT NAVAJO AT END OF WASHDOWN (H + 9.4)

	Lower Limit	Observed	Upper Limit
E_{TD}	82	87	90
E_{TR}	82	87	90.4

TABLE 3.5 YAG-40 OPERATIONAL DATA FOR SHOT ZUNI

Type of fallout	Particulate coral residue
Distance from GZ	52 miles north
Surface wind velocity	20 knots 065°
Rain during washdown	5 to 10 min at H + 7, 15 min at H + 8
Course and maneuver	H + 3 to H + 6, 270° at 11 knots; H + 6 to H + 15, 045° at 2 knots
Time of:	
First rise in background	H + 3.0
Fallout start	H + 3.4
Peak air dose rate	H + 5.9
Peak deck dose rate	H + 6.8
End of fallout	H + 8.2
Washdown on	H + 3.3
Washdown off	H + 15.5
Peak mean dose rate:	
Washed area	1.58 r/hr
Unwashed area	6.84 r/hr
Mean total dose at end of washdown:	
Washed area	8.73 r
Unwashed area	41.6 r
Time washdown continued after fallout cessation	7.3 hr

TABLE 3.6 SIGNIFICANT WASHDOWN EFFECTIVENESS (PERCENT), SHOT ZUNI

	At Time of Peak Dose Rate Air Contribution (H + 5.9)			At Time of End of Washdown (H + 15.5)		
	Lower Limit	Observed	Upper Limit	Lower Limit	Observed	Upper Limit
E_{TD}				72	79	84.5
E_{TR}				81	85.5	89
E_{DD}				72	83	91
E_{DR}	76	93	100	81.5	85	87.5

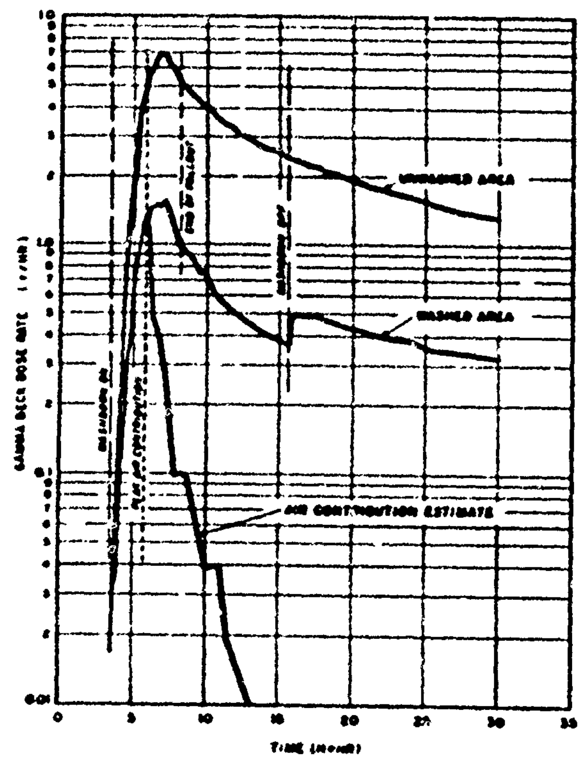


Figure 3.16 Average gamma deck dose rates from washed and unwashed areas and the estimate from the washed area of dose rate contributed by air-borne contaminants versus time after Shot Zuni on YAG-40.

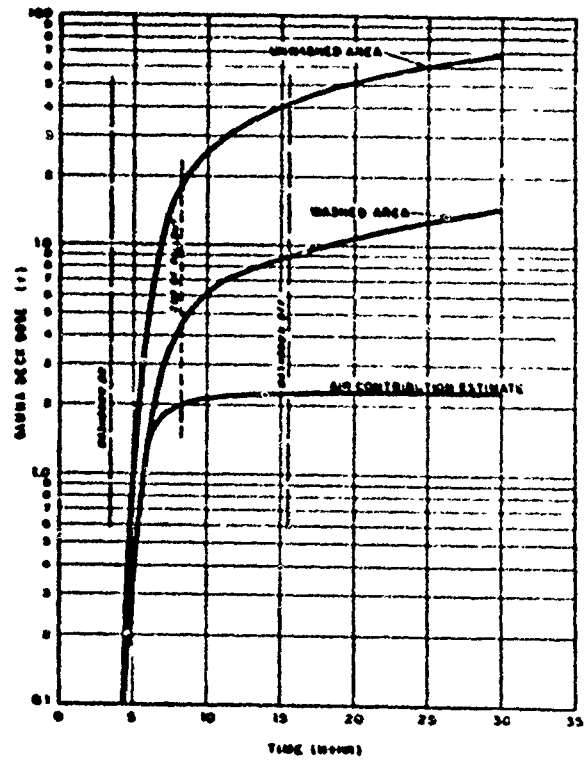


Figure 3.17 Average accumulated gamma deck doses from washed and unwashed areas and the washed area estimate of dose contributed by air-borne contaminants versus time after Shot Zuni on YAG-40.

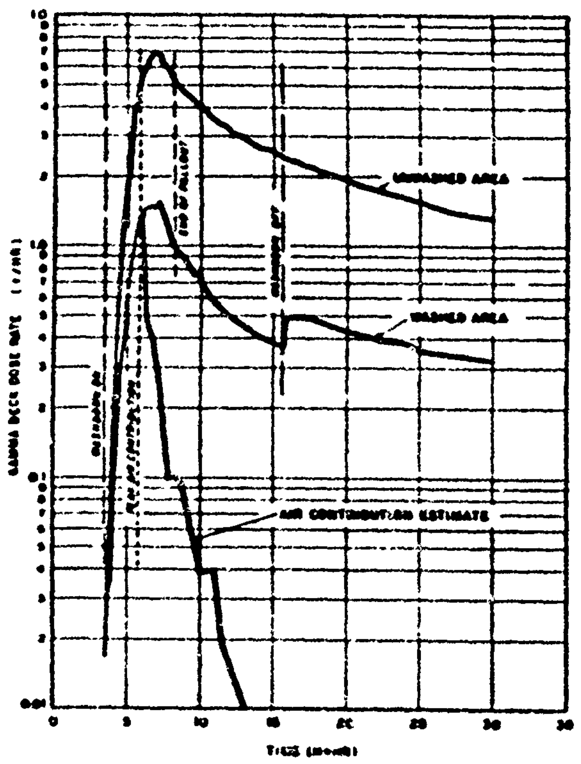


Figure 3.16 Average gamma deck dose rates from washed and unwashed areas and the estimate from the washed area of dose rate contributed by air-borne contaminants versus time after Shot Zuni on YAG-40.

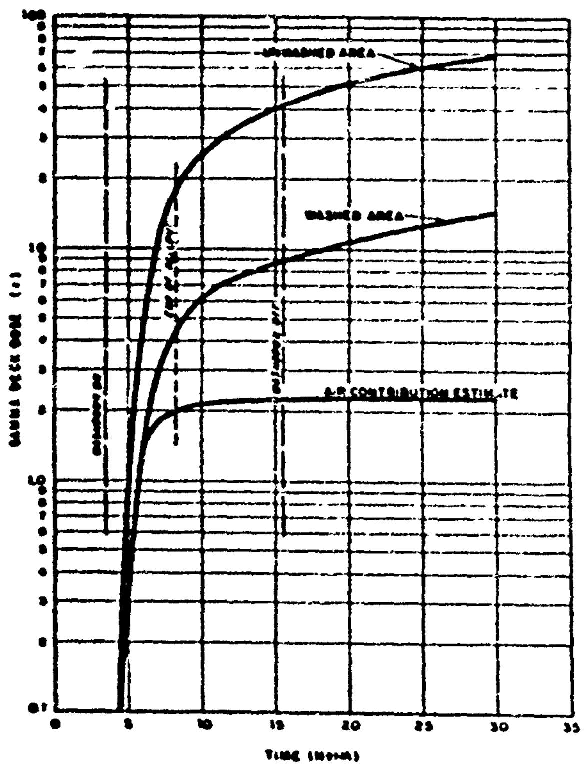


Figure 3.17 Average accumulated gamma deck doses from washed and unwashed areas and the washed area estimate of dose contributed by air-borne contaminants versus time after Shot Zuni on YAG-40.

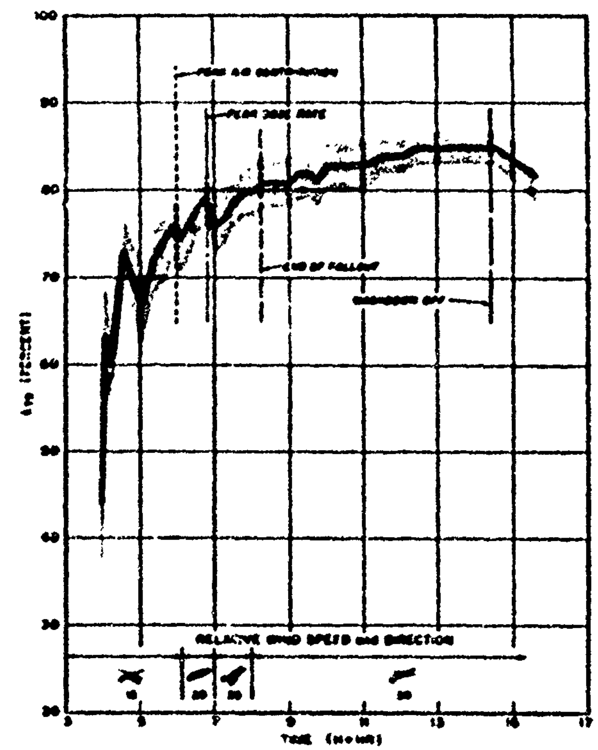


Figure 3.18 Washdown effectiveness based on reduction of total dose rate versus time after Shot Zuni on YAG-40. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

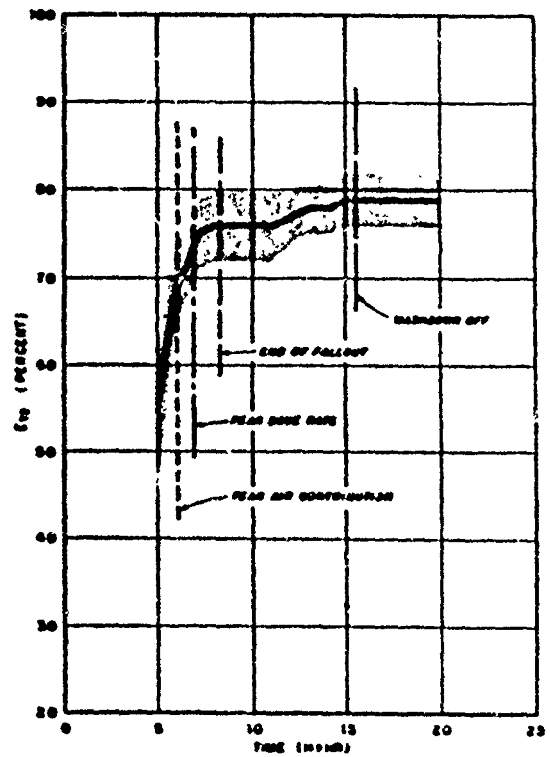


Figure 3.19 Washdown effectiveness based on reduction of total dose versus time after Shot Zuni on YAG-40. Shaded area indicates estimate of uncertainty.

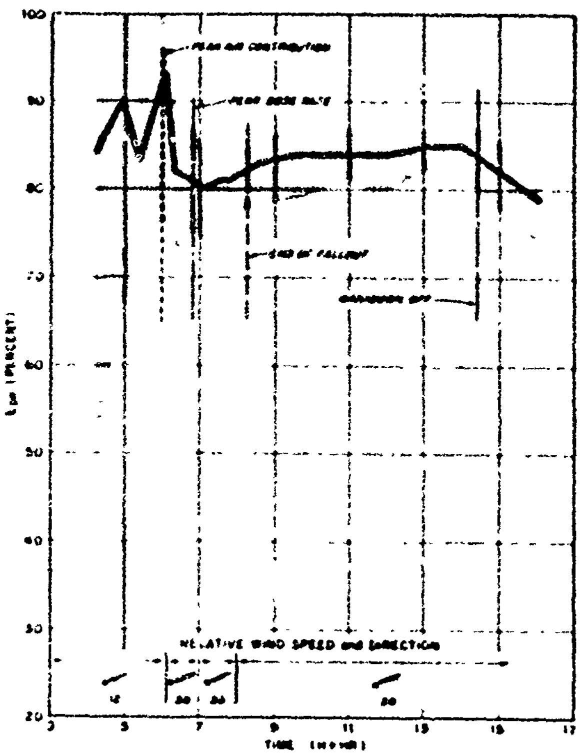


Figure 3.20 Washdown effectiveness based on reduction of deposit dose rate versus time after Shot Zuni on YAG-40. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

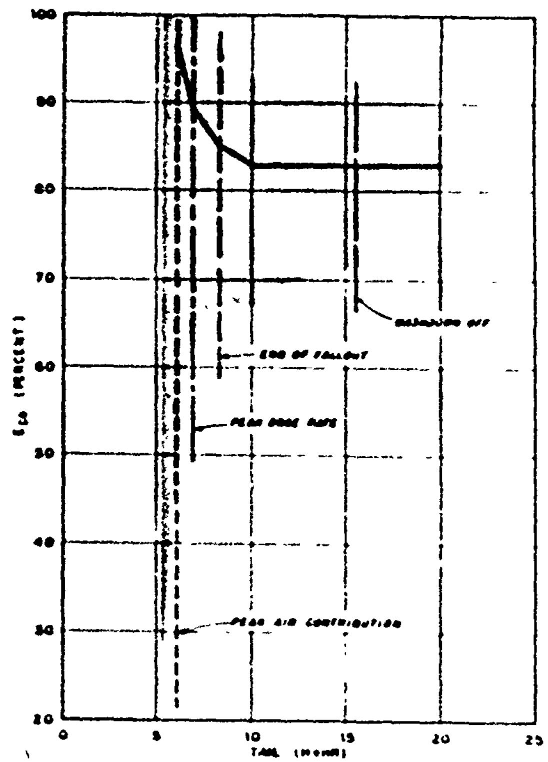


Figure 3.21 Washdown (ectiveness based on reduction of deposit dose versus time after Shot Zuni on YAG-40. Shaded area indicates estimate of uncertainty.

3.5.2 Shot Tewa, YAG-39. Operational Data (YAG-39). A statement of the significant operational data for YAG-39, Tewa is given in Table 3.7. Figure 3.22 is a track chart for both YAG's during the Tewa participation. YAG-39 kept station with a combination of the "slow-into-the-wind" procedure and the figure-eight maneuver.

Note that the start of fallout coincides with the first indication of a rise in background and that from the start of fallout to the peak air dose rate only two and a half hours elapsed, indicating a rapid rate of fallout arrival.

Notice also that during this time of rapid fallout arrival, the washdown was secured from H + 2.7 to H + 3.1, and then was operated intermittently. This was done to allow access to the deck for personnel from other projects.

Radiation and Washdown Effectiveness Data (YAG-39). The estimate

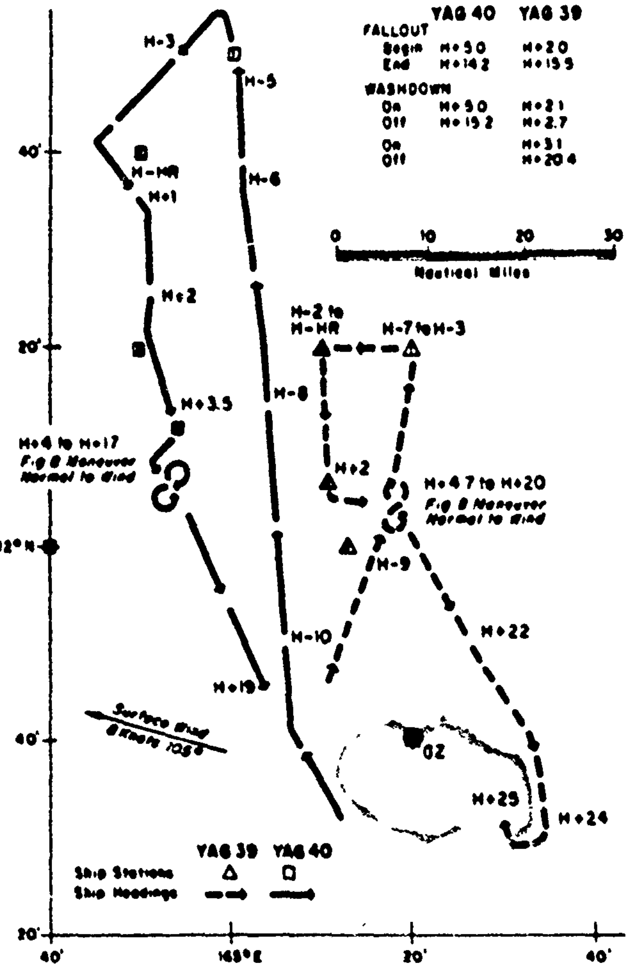


Figure 3.22 Tracks made by YAG's 39 and 40 during Shot Tewa participation.

of air contribution in the unwashed area and the washed area and total gamma deck dose rates and doses are presented in Figures 3.23 and 3.24.

The data from Station 70 in the washed area was rendered unsuitable for estimation of the contribution to the radiation field on deck from air-borne contaminant by the intermittent action of the washdown.

In Figure 3.23, notice the very steep rise in dose rate in the washed area prior to H + 3 hours and the lesser slope after H + 3, almost exactly coincident with reactivation of the

Continued on Page 46

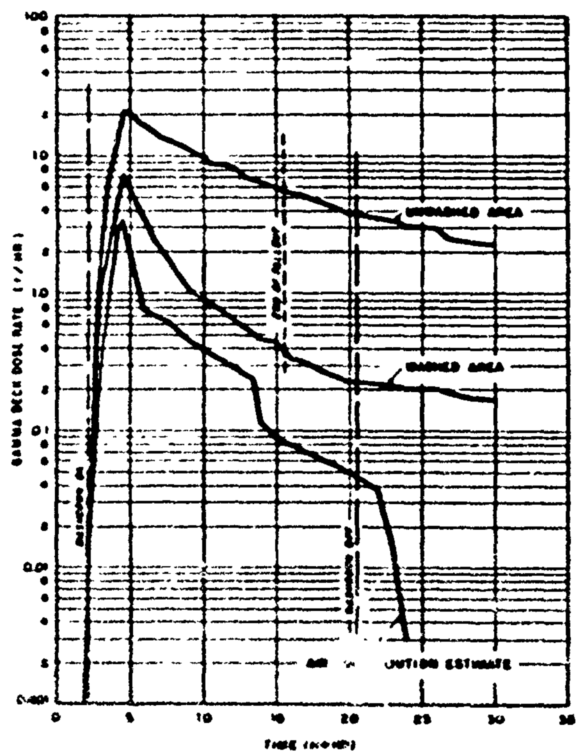


Figure 3.23 Average gamma deck dose rates from washed and unwashed areas and the estimate from the unwashed area of the dose rate contributed by air-borne contaminants versus time after Shot Tewa on YAG-39.

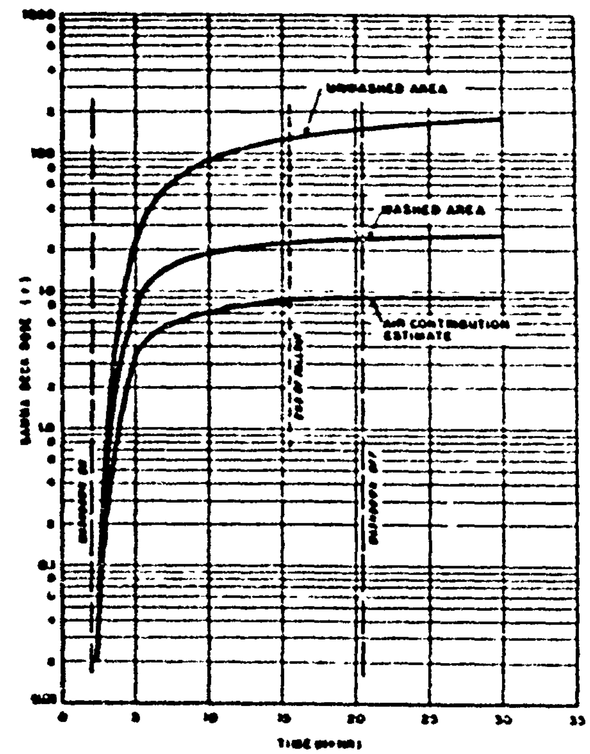


Figure 3.24 Average accumulated gamma deck doses from washed and unwashed areas and the unwashed area estimate of dose contributed by air-borne contaminants versus time after Shot Tewa on YAG-39.

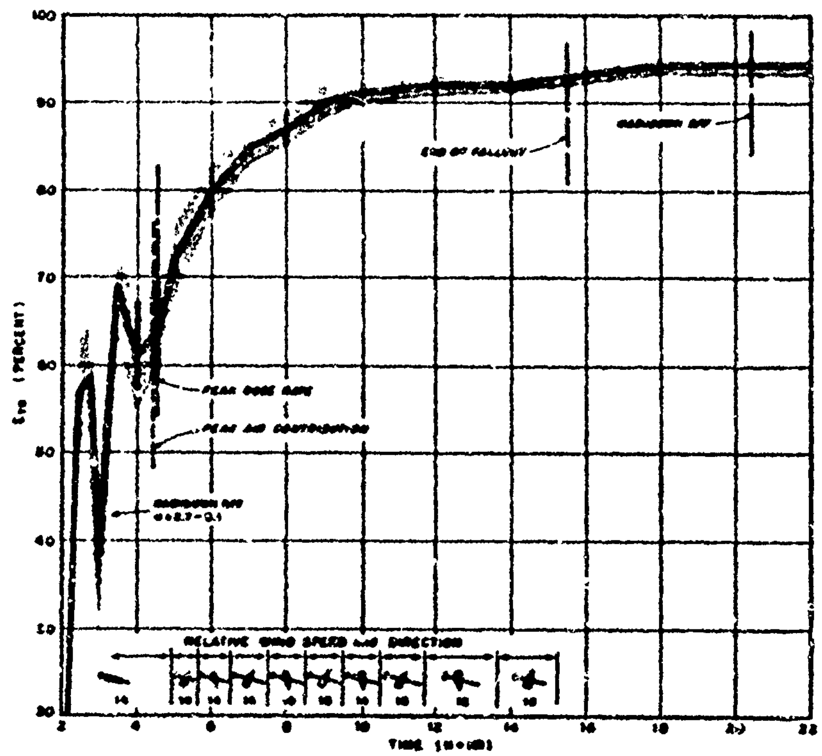


Figure 3.25 Washdown effectiveness based on reduction of total dose rate versus time after Shot Tewa on YAG-39. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

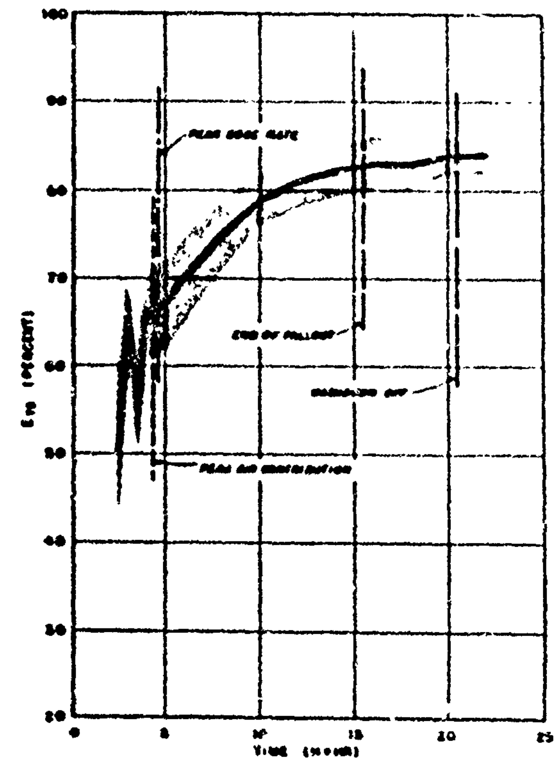


Figure 3.26 Washdown effectiveness based on reduction of total dose versus time after Shot Tewa on YAG-39. Shaded area indicates estimate of uncertainty.

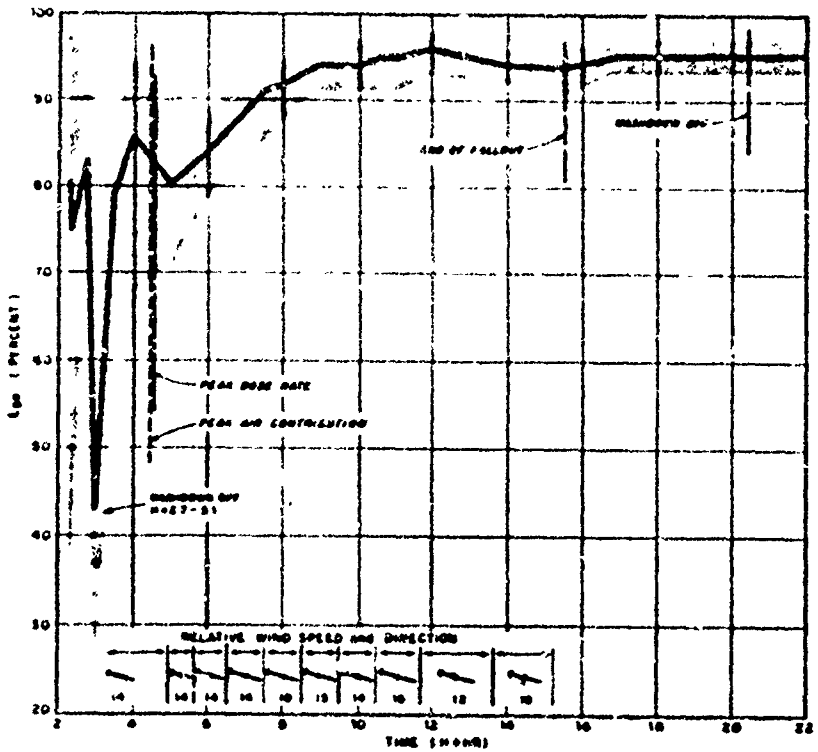


Figure 3.27 Washdown effectiveness based on reduction of deposit dose rate versus time after Shot Tewa on YAG-39. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

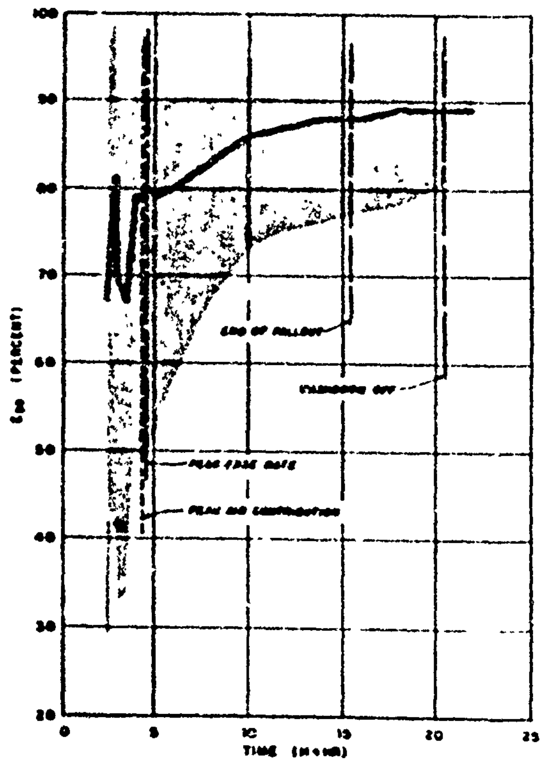


Figure 3.28 Washdown effectiveness based on reduction of deposit dose versus time after Shot Tewa on YAG-39. Shaded area indicates estimate of uncertainty.

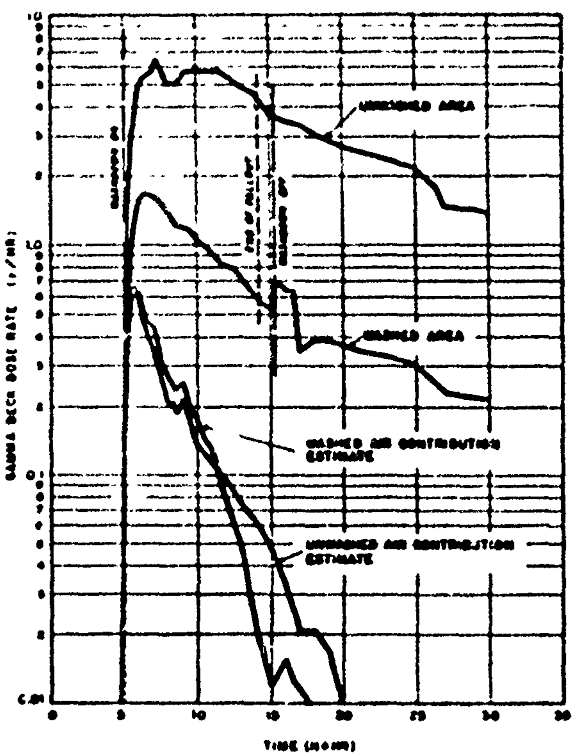


Figure 3.29 Average gamma deck dose rates and estimates of dose rates contributed by air-borne contaminants from washed and unwashed areas versus time after Shot Tewa on YAG-40.

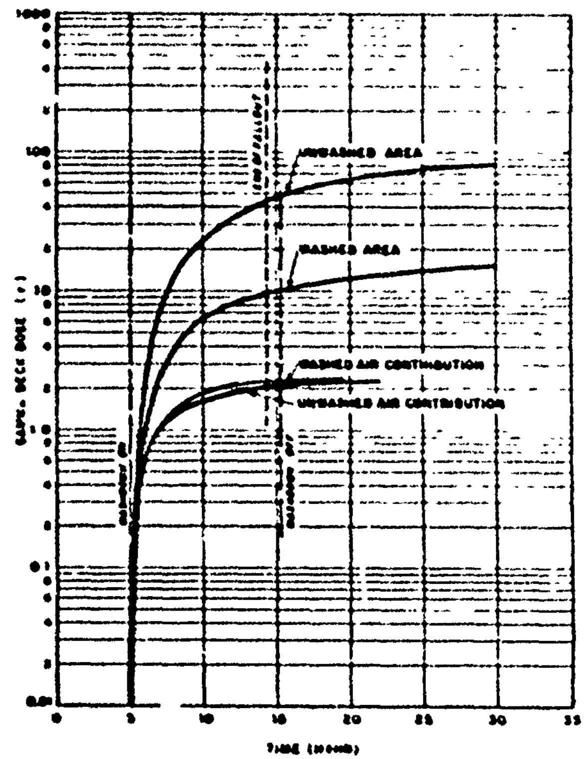


Figure 3.30 Average accumulated gamma deck doses and estimates of doses contributed by air-borne contaminants from washed and unwashed areas versus time after Shot Tewa on YAG-40.

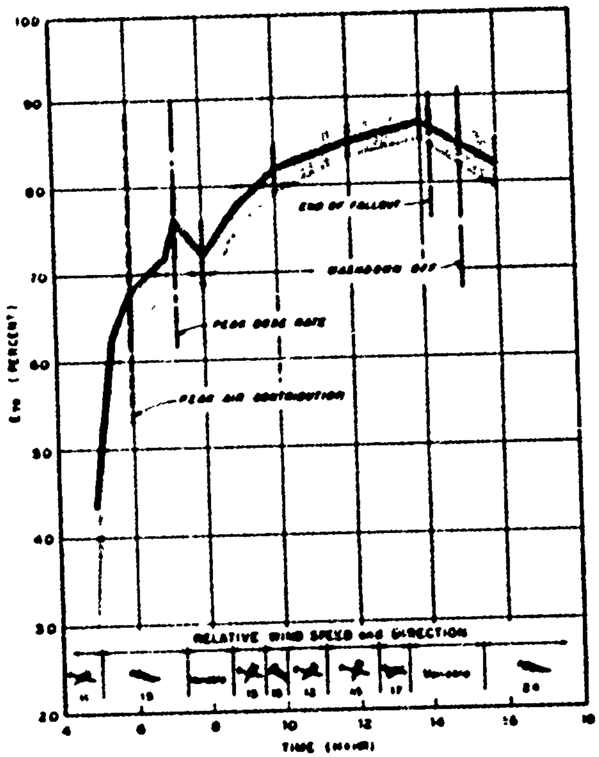


Figure 3.31 Washdown effectiveness based on reduction of total dose rate versus time after Shot Tewa on YAG-40. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

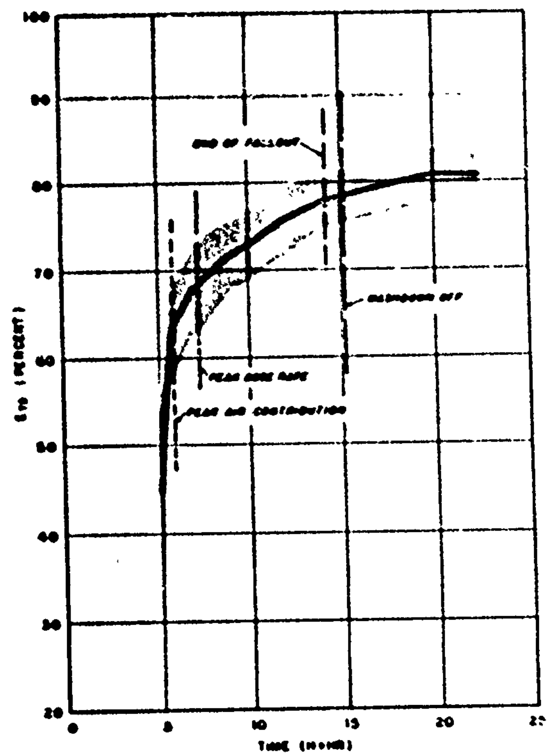


Figure 3.32 Washdown effectiveness based on reduction of total dose versus time after Shot Tewa on YAG-40. Shaded area indicates estimate of uncertainty.

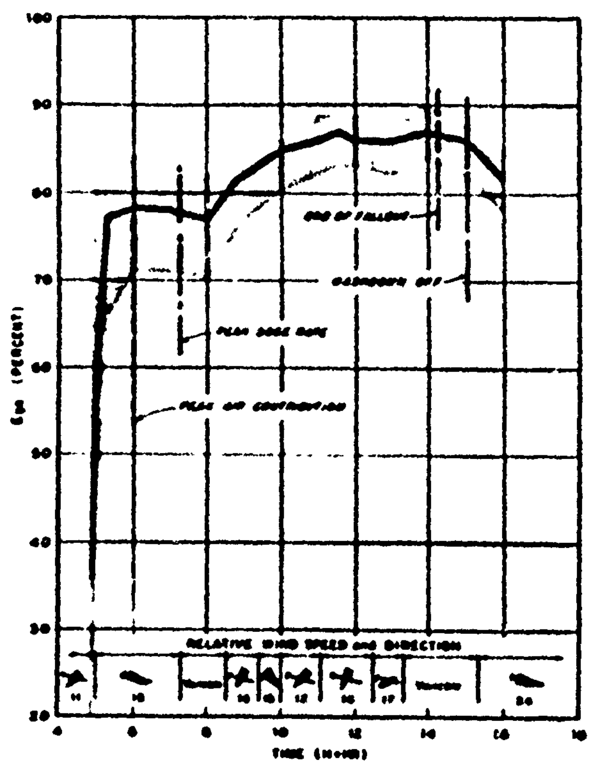


Figure 3.33 Washdown effectiveness based on reduction of deposit dose rate versus time after Shot Tewa on YAG-40. Shaded area indicates estimate of uncertainty. Ship silhouettes indicate approximate headings and arrows indicate relative wind direction. Wind speeds are in knots.

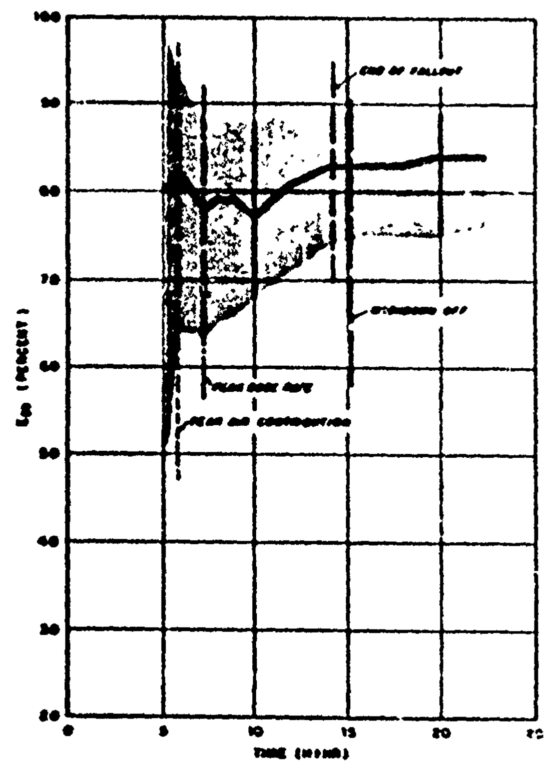


Figure 3.34 Washdown effectiveness based on reduction of deposit dose versus time after Shot Tewa on YAG-40. Shaded area indicates estimate of uncertainty.

TABLE 3.7 YAG-39 OPERATIONAL DATA FOR SHOT TEWA

Type of contaminant	Particulate coral residue
Distance from GZ	25 miles north
Surface wind velocity	8 knots 105°
Rain during washdown	None
Course and maneuver	H + 2 to H + 4.7, 110° at 2 knots H + 4.7 to H + 20, figure eight perpendicular to wind
Time of:	
First rise in background	H + 2.0
Fallout start	H + 2.0
Peak air dose rate	H + 4.5
Peak deck dose rate	H + 4.6
End of fallout	H + 15.5
Washdown on	H + 2.1
Washdown off	H + 2.7
Washdown on	H + 3.1
Washdown off	H + 9.7
Washdown on	H + 10.2
Washdown off	H + 10.8
Washdown on	H + 11.3
Washdown off	H + 13.9
Washdown on	H + 15.1
Washdown off	H + 15.7
Washdown on	H + 15.8
Washdown off	H + 16.2
Washdown on	H + 16.9
Washdown off	H + 17.6
Washdown on	H + 17.7
Washdown off	H + 18.6
Washdown on	H + 18.7
Washdown off	H + 20.4
Peak mean dose rate:	
Washed area	7.54 r/hr
Unwashed area	21.2 r/hr
Mean total dose at end of washdown:	
Washed area	23.9 r
Unwashed area	149 r
Time washdown continued after fallout cessation	4.9 hr

TABLE 3.8 SIGNIFICANT WASHDOWN EFFECTIVENESS (PERCENT), SHOT TEWA, YAG-39

	At Time of Peak Dose Rate Air Contribution (H + 4.5)			At Time of End of Washdown (H + 20.4)		
	Lower Limit	Observed	Upper Limit	Lower Limit	Observed	Upper Limit
E_{TD}				78	84	88
E_{TR}				91.5	94	95.5
E_{DD}				80	89	96
E_{DR}	70	83	90	93	96	97

TABLE 3.9 YAG-40 OPERATIONAL DATA FOR SHOT TEWA

Type of contaminant	Particulate coral residue
Distance from GZ	40 miles northwest
Surface wind velocity	8 knots 105°
Rain during washdown	None
Course and maneuver	H+4.7 to H+17, figure eight perpendicular to the wind
Time of:	
First rise in background	H+4.3
Fallout start	H+5.0
Peak air dose rate	H+5.8
Peak deck dose rate	H+7.3
End of fallout	H+14.2
Washdown on	H+5.0
Washdown off	H+15.2
Mean dose rate peak	
Washed area	1.70 r/hr
Unwashed area	6.46 r/hr
Mean total dose at end of washdown:	
Washed area	10.3 r
Unwashed area	49.3 r
Time washdown continued after fallout cessation	1.0 hr

TABLE 3.10 SIGNIFICANT WASHDOWN EFFECTIVENESS (PERCENT), SHOT TEWA, YAG-40

	At Time of Peak Dose Rate Air Contribution (H+5.8)			At Time of End of Washdown (H+15.2)		
	Lower Limit	Observed	Upper Limit	Lower Limit	Observed	Upper Limit
E_{TD}				72	79	85
E_{TR}				83	87	91
E_{DD}				74	83	89
E_{DR}	71	78	84	82	86	88

TABLE 3.11 TOTAL DECK DOSE SAVED BY WASHDOWN (E_{TD} AT THE END OF WASHDOWN)

		Lower Limit	Observed	Upper Limit	Average
		pct	pct	pct	absolute r
Particulate Fallout	Tewa, YAG-39	78	84	88	128
	Zuni, YAG-40	72*	79*	84.5*	32.9*
	Tewa, YAG-40	72	79	85	39.0
Slurry Fallout	Flathead, YAG-40	94.5	96	97	2.91
	Navajo, YAG-39	82	87	90	4.76

* Values reduced by rain.

TABLE 3.12 PERCENT FUTURE DECK DOSE SAVED BY WASHDOWN (E_{TR} AT THE END OF WASHDOWN)

		Lower Limit	Observed	Upper Limit
Particulate Fallout	Tewa, YAG-39	91.5	94	95.5
	Tewa, YAG-40	83	87	91
	Zuni, YAG-40	81 *	85.5 *	89 *
Slurry Fallout	Flathead, YAG-40	96	97	98
	Navajo, YAG-39	82	87	90.4

* Values reduced by rain.

TABLE 3.13 PERCENT REMOVAL OF DEPOSITED CONTAMINANT (E_{DD} AT THE END OF WASHDOWN)

		Lower Limit	Observed	Upper Limit
Particulate Fallout	Tewa, YAG-39	80	89	96
	Zuni, YAG-40	72 *	83 *	91 *
	Tewa, YAG-40	74	83	89

* Values reduced by rain.

TABLE 3.14 PERCENT FUTURE DOSE SAVED BY WASHDOWN (E_{DR} AT THE END OF WASHDOWN)

		Lower Limit	Observed	Upper Limit
Particulate Fallout	Tewa, YAG-39	93	96	97
	Tewa, YAG-40	82	86	88
	Zuni, YAG-40	78 *	81 *	84 *

* Values reduced by rain.

TABLE 3.15 PERCENT REMOVAL OF DEPOSITED CONTAMINANT AT TIME OF MAXIMUM ARRIVAL RATE (E_{DR})

	Lower Limit	Observed	Upper Limit
Zuni, YAG-40	76	93	100
Tewa, YAG-39	70	83	90
Tewa, YAG-40	71	78	84

washdown system at H + 3.1. Also, the air-contribution dose-rate estimate indicates the possible presence of air-borne activity which did not fall out on the ship.

In Figure 3.24, the time of fallout cessation, as determined from the Project 2.63 collectors, agrees closely with the start of the constant portion of the air contribution dose estimate curve.

Washdown effectiveness is presented in Figures 3.25 through 3.28. The drop in effectiveness shown in all of the curves marks closely the time when the washdown was turned off at H + 2.7.

Relative wind-speed-and-direction data from the approximate end of fallout to the end of washdown is not available. See Table 3.8 for a summary of important effectiveness values from YAG-39 during the Tewa exercise.

3.5.3 Shot Tewa, YAG-40. Operational Data (YAG-40). Table 3.9 and Figure 3.22 display pertinent operational data for the Tewa participation of YAG-40.

In this case, station keeping was done using the figure-eight procedure exclusively.

Radiation and Washdown Effectiveness Data (YAG-40). The dose rate and dose data for the air-borne contribution (both in the washed and unwashed areas from Stations 70 and 3 respectively), and total dose and dose-rate data from the washed and unwashed areas are shown in Figures 3.29 and 3.30.

This is the only case where it was possible to estimate the contribution to the radiation field from air-borne contaminants in both the washed and unwashed areas.

The dose rate in the washed area exhibits an increase at the end of washdown in Figure 3.29 as occurred on the YAG-40 during the Zuni participation (Figure 3.16).

The end of fallout, as evidenced by the flattening of the air contribution dose curves in Figure 3.30, approximates again the end of fallout as measured by the Project 2.63 instruments.

The effectiveness results are given in Figures 3.31 through 3.34.

In Figures 3.31 and 3.33, the drop in effectiveness based on reduction of dose rate (E_{TR} and E_{DR}) after the end of washdown is due to the jump in dose rate in the washed area. The dip in the effectiveness curves in the same figures at approximately H + 8 hours is due to the drop in dose rate in the unwashed control area at that time. See Figure 3.29.

The important values from these curves are given in Table 3.10.

3.6 SUMMARY OF WASHDOWN EFFECTIVENESS RESULTS

Tables 3.11 through 3.15 summarize the results.

Chapter 4
DISCUSSION

4.1 MILITARY SIGNIFICANCE OF RADIATION LEVELS ENCOUNTERED

As noted in Chapter 3, the gamma radiation hazard recorded on the test ships was not particularly dangerous, with the possible exception of that on the YAG-39 during Tewa sorties.

According to preliminary estimates contained in the Program 2 Summary, "Fallout Studies During Operation Redwing" (Reference 11), the radiation hazard encountered on the test ships could have been as much as 10 times as great, had they been positioned differently.

This is not to infer that the washdown effectiveness would have been the same with this additional amount of fallout, but to point out that situations could have existed where washdown would have been more of a military necessity than it was aboard the test ships during Operation Redwing.

4.2 EFFECT OF POSSIBLE VARIATIONS IN AMOUNT OF FALLOUT IN WASHED AND CONTROL AREAS

Washdown evaluation by comparison of radiation measurements taken in the forward and aft sections of a ship cannot be considered ideal although it is preferable to the use of independently operated ships as test and control areas. Weather surface geometry, changing fallout particle size, and wind speed and direction are interrelated factors which cause differences in the amounts of contaminant delivered fore and aft.

Radiation measurements taken during two sorties of the YAG-40 (without washdown) during Operation Castle show that doses accumulated aft were higher than forward by 8 and 30 percent when the wind was aft or on the beam. With the wind over the bow on the third sortie, the dose aft was lower by 17 percent than the dose forward.

The figure-eight maneuver broadside to the wind, used on 3 sorties, and running before the wind on one, during Redwing, would, on the basis of the above data, provide test conditions leading to low values for washdown effectiveness. One run was made with the wind on the bow, a condition which would tend to provide inflated values for effectiveness. Table 4.1 presents the maximum and minimum measured values for washdown effectiveness and based on the above-mentioned Castle experience, the possible actual values for both relative wind conditions. Since the Castle data applies primarily to the slurry-type fallout, no estimate can be made of the effect of varying physical characteristics of the contaminant.

No attempt has been made to apply these corrections generally to the Redwing data because of the high degree of uncertainty involved. Also, it is apparent from Table 4.1 that windspeeds were lower during Operation Redwing than during Operation Castle and so it is expected that fore and aft variations in amount of contaminant would have been less. It is felt that these test conditions do not seriously prejudice the results.

4.3 EFFECT OF INCOMPLETE WASHDOWN COVERAGE

4.3.1 E_{TD} and E_{TR}. In Figures 1.1 and 1.2, it can be seen that the kingpost in the

washed area of both ships was not thoroughly covered by the spray. Contaminant on the kingpost, which is close to the washed area detectors, would tend to make the readings in the washed area higher than if this condition had not existed. Thus, the effectiveness based on reduction of total dose and dose rate (E_{TD} and E_{TR}) as measured, is less than it would have been if: (the kingpost had been thoroughly washed, and (2) the washed area detectors had been located farther from the kingpost.

4.3.2 E_{DD} and E_{DR}. Station 70, from which data was obtained to estimate the airborne contaminant contribution in the washed area, is shielded so as not to be influenced by radiation from the kingpost. Therefore, the radiation from this source was not subtracted out with the air contribution estimate, and the effectiveness values based on removal of deposited material (E_{DD} and E_{DR}) are biased unfavorably, since the washdown is charged with not having removed contaminant which it could not reach.

This factor is a function of the design of the washdown system, but the cases in point are typical since masts, antennae, etc., are often left untouched by existing shipboard washdown systems.

4.4 FACTORS INFLUENCING WASHDOWN EFFECTIVENESS (SLURRY CONTAMINANTS)

4.4.1 Shot Flathead, YAG-40. The fallout period was long, the amount of material deposited was apparently slight, and the fallout particles were small. These factors combined to make for exceptional washdown effectiveness.

4.4.2 Shot Navajo, YAG-39. Unfortunately, the washdown was secured before the Navajo fallout had ceased. This fact, coupled with intermittent operation, prevented the washdown from achieving maximum effectiveness.

4.5 FACTORS INFLUENCING WASHDOWN EFFECTIVENESS (PARTICULATE CONTAMINANTS)

4.5.1 Shot Zuni, YAG-40. The relative wind blowing from the quarter for the first 3 hours of fallout may have reduced the effectiveness of the washdown. The rain traversed by the YAG-40 during the Zuni fallout period removed some contaminant from the unwashed control area, thereby reducing the radiation level there, without a corresponding reduction in the washed area. The resulting effect was a false reduction of effectiveness values. Continuation of washdown for 7 hours after the end of fallout increased washdown effectiveness 3 to 5 percent above the effectiveness at the end of fallout.

4.5.2 Shot Tewa, YAG-39. The intermittent operation of the washdown system certainly had an adverse effect on the washdown effectiveness early in the fallout period, and had it been operated continuously, greater effectiveness would have been achieved, particularly effectiveness based on dose reduction.

Continuation of the washdown for 5 hours after the cessation of fallout increased the effectiveness.

4.5.3 Shot Tewa, YAG-40. Continuous operation of the washdown system was practiced, but the washdown was secured only 1 hour after the end of fallout. If washdown

had been continued longer, effectiveness would have increased. The drop in dose rate of H + 17 hours was due to decontamination by ship's force at that time.

4.5.4 Shots Zuni and Tewa, YAG-40. An abrupt rise in dose rate in the washed area on YAG-40 coincided with the turning off of the washdown during both Zuni and Tewa. This phenomenon occurred only on YAG-40 and was noticeable only with particulate type of fallout. Possible causes for this occurrence follow:

1. Contaminant collected near the ship's rail and around nearby drains could have been shielded by the slant thickness of washdown water on deck between the contaminant and the detector. When the washdown system was secured, the water drained over the side, the shielding was removed, and the dose rate seen by the detector increased.

If the above is assumed to be correct then differences in drainage may have been the reason why a similar increase in dose rate was not observed on the YAG-39 during Tewa. On this ship there is no bulwark or rail near the detector in the washed area to hinder the

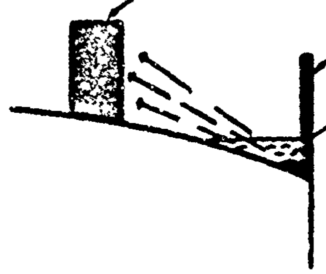


Figure 4.1 Sketch demonstrating how bulwark on YAG-40 could collect washdown runoff and contaminant. Not to scale.

discharge of water over the side, as on the YAG-40. It is also possible that differences in trim may have favored a build-up of water in this area on the YAG-40 while favoring runoff on the YAG-39.

2. Additional fallout could have arrived at this time, although the contribution to deck dose rates from air-borne contaminant does not clearly indicate that this is the case. A small constant change in dose rate in both test areas would be more noticeable in the washed area than in the unwashed section.

3. Preferential removal by the washdown of one or more isotopes may have disturbed parent-daughter equilibria, resulting in temporary changes in decay rate until equilibrium was restored. Indication of this phenomenon was reported following ship and aircraft decontamination at Operation Castle (Reference 1). However, it is difficult to explain why this was not apparent in the YAG-39, Tewa dose-rate curves.

4.6 REDWING AND CASTLE COMPARISON

Table 4.2 presents a summary of Operations Redwing and Castle results. The fallout encountered by the YAG's during Operation Castle had the same physical characteristics as that from Shots Flathead and Navajo during the Redwing series, though referred to as a fine mist during Castle and a slurry during Redwing (References 1 and 9).

4.7 WASHDOWN EFFECTIVENESS AGAINST PARTICULATE FALLOUT

Table 4.2 indicates that when particulate contaminant was encountered, washdown was

TABLE 4.1 POSSIBLE VARIATIONS BETWEEN OBSERVED AND ACTUAL WASHDOWN EFFECTIVENESS DUE TO RELATIVE WIND SPEED AND DIRECTION, OPERATION REDWING

Principal Wind Direction	Range of Relative Wind Speed	Range of Observed Effectiveness	Range of Possible Actual Effectiveness
	knots	E_{TD} pct	E_{TD} pct
Abeam and Astern (Figure 8 maneuver and Shot Zuni participation)	10 to 20 (Castle 15 to 25)	79 to 87	80 to 91
Wind over Bow (Shot Flathead)	15 to 17 (Castle 25 to 30)	96	96

TABLE 4.2 WASHDOWN EFFECTIVENESS SUMMARY OF CASTLE AND REDWING RESULTS

	Castle	Redwing
	pct	pct
Slurry Contaminant:		
End of fallout		
E_{TD}	87 to 94	96 to 97
E_{TR}	90 to 96	96 to 98
End of washdown	2 hours after end of fallout	1.5 hours after end of fallout
E_{TD}	89 to 96	96 to 98
E_{TR}	93 to 97	96 to 97
Particulate Contaminant:		
End of fallout	No washdown evaluation of this type of contaminant during Operation Castle	
E_{TD}		76 to 86
E_{TR}		85 to 94
End of washdown		5 hours after end of fallout
E_{TD}		82 to 86
E_{TR}		93 to 95

less effective, but with continued washing after fallout had ceased, the reduction in dose rate approached the effectiveness achieved against the slurry contaminant.

4.8 WASHDOWN OPERATING CONDITIONS FOR MAXIMUM EFFECTIVENESS

The following stipulations are put forth for achieving maximum washdown effectiveness. Washdown should: (1) be activated as soon as possible after fallout arrival is detected; (2) be operated continuously, particularly from beginning of fallout through the time when the peak dose rate is reached; and (3) be operated as long as possible after fallout ceases.

4.9 EFFECT OF SHIP DESIGN ON WASHDOWN EFFECTIVENESS

Study of Figures 3.11 through 3.14 reveals that collection of fallout material could be greatly reduced by changes in the configuration of the weather surfaces of ships. Deck seams, areas with poor drainage, gun tubs and other projections on the weather decks are points where the contaminant collected. Washdown would be more effective on a more streamlined ship. (see Figure 4.1).

Chapter 5
CONCLUSIONS and RECOMMENDATIONS

5.1 CONCLUSIONS

Four conclusions can be drawn from the results of this test. They are:

1. The washdown effectiveness, as reported from Operation Castle, is substantiated when employed against a slurry-type contaminant.
2. Lesser effectiveness, 76 to 86 percent versus 87 to 97 percent reduction of total gamma dose at the end of fallout was achieved against the Zuni-Tewa coral residue fallout.
3. Maximum washdown effectiveness is achieved by prompt activation at the start of the contaminating event and by continuous operation as long as possible after the fallout has ceased. Washing after fallout cessation is particularly advantageous in the case of the particulate contaminant.
4. Washdown effectiveness can be materially increased by smooth and well-drained ship weather surfaces.

5.2 RECOMMENDATIONS

It is desirable to extend knowledge of the value of the washdown countermeasure under two additional circumstances beyond those obtained in past tests and applicable to ships at sea or shore approaches. They are: (1) under contaminating conditions produced by a relatively shallow underwater burst with its attendant base surge and fallout, which would contaminate at very early times after burst in a short time interval, and presumably to a greater degree than in previous experiences, and (2) under contaminating conditions of a water surface burst in a region of intense fallout such as might have been encountered in this test series (Reference 11) where high (lethal) radiation dose would be encountered.

It is therefore recommended that washdown evaluations be accomplished under the above circumstances.

Appendix

SAMPLE CALCULATIONS

A.1 E_{TD} AND E_{TR}

The method used for handling the limits of accuracy when applied to the radiation measurements in Equation 1.1 and 1.2 is as follows:

$$E_{TD} = 100\left[1 - \frac{D_w}{D_u}\right] \tag{1.1}$$

$$E_{TD} = 100\left[1 - \frac{R_w}{R_u}\right] \tag{1.2}$$

In solving Equations 1.1 and 1.2 the ratios D_w/D_u and R_w/R_u were determined. The ±15 percent limits for D_w, D_u, R_w, and R_u were calculated and applied to each to determine maximum and minimum values. Maximum and minimum ratios were calculated using D_w max/D_u min, R_w max/R_u min, D_w min/D_u max, and R_w min/R_u max. Ratios were then substituted in Equations 1.1 and 1.2 to yield average, maximum, and minimum effectiveness values. Example:

E_{TD}, YAG-40, Flathead at end of washdown

$D_w = 0.127$ r, max $D_w = D_w + 0.15\ D_w = 0.146$, min $D_w = D_w - 0.15\ D_w = 0.108$

$D_u = 3.10$ r, max $D_u = D_u + 0.15\ D_u = 3.565$, min $D_u = D - 0.15\ D_u = 2.335$

$$\frac{D_w}{D_u} = 0.04 \qquad \frac{\max D_w}{\min D_u} = 0.055 \qquad \frac{\min D_w}{\max D_u} = 0.03$$

$$E_{TD}\ (\max) = 100\left[1 - \frac{D_w \min}{D_u \max}\right] = 100\ [1 - 0.03] = 97 \text{ percent}$$

$$E_{TD}\ (\text{avg}) = 100\left[1 - \frac{D_w}{D_u}\right] = 100\ [1 - 0.04] = 96 \text{ percent}$$

$$E_{TD}\ (\min) = 100\left[1 - \frac{D_w \max}{D_u \min}\right] = 100\ [1 - 0.055] = 94.5 \text{ percent}$$

A.2 E_{DD} AND E_{DR}

Calculation of E_{DD} and E_{DR}, Equation 1.3 and 1.4, was accomplished as follows:

$$E_{DD} = 100\left[1 - \frac{D_w - a}{D_u - a}\right] \tag{1.3}$$

$$E_{DR} = 100\left[1 - \frac{R_w - A}{R_u - A}\right] \tag{1.4}$$

Maximum and minimum values for the ratios $(D_w - a)/(D_u - a)$ and $(R_w - A)/(R_u - A)$ were determined by substitution of values so that the largest possible numerator was divided by the smallest denominator pro-

ducing a maximum value and vice versa for the minimum. This method was chosen so that the final limits on effectiveness reflect the widest probable range. Example:

E_{DD}, YAG-40, Zuni at the end of washdown

	Min.	Max.	Avg.	Remark
D_w =	7.40	10.0	8.71	Avg ±15 percent
D_u =	35.2	47.6	41.4	Avg ±15 percent
a =	1.11	3.32	2.21	Estimate ±50 percent

$$\text{Minimum } E_{DD} = 100\left[1 - \frac{\text{Max } D_w - \text{Min a}}{\text{Min } D_u - \text{Max a}}\right]$$

$$= 100\left[1 - \frac{10.0 - 1.11}{35.2 - 3.32}\right]$$

$$= 100\left[1 - \frac{8.89}{31.9}\right]$$

$$= 100\left[1 - 0.28\right] = 72 \text{ percent}$$

$$\text{Maximum } E_{DD} = 100\left[1 - \frac{\text{Min } D_w - \text{Max a}}{\text{Max } D_u - \text{Min a}}\right]$$

$$= 100\left[1 - \frac{7.40 - 3.32}{47.6 - 1.11}\right]$$

$$= 100\left[1 - \frac{4.08}{46.5}\right]$$

$$= 100\left[1 - 0.09\right] = 91 \text{ percent}$$

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142 Deputy Chief of Staff, Operations, HQ. USAF, Washington 25, D.C. ATTN: AFOOP

143 Deputy Chief of Staff, Operations HQ. USAF, Washington 25, D.C. ATTN: Operations Analysis

144 Director of Installations, HQ. USAF, Washington 25, D.C. ATTN: AFOIE-E

145-146 Assistant Chief of Staff, Intelligence, HQ. USAF, Washington 25, D.C. ATTN: AFCIN-1B2

147 Director of Research and Development, DCS/D, HQ. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.

148 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division

149 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: CAWS

150 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch

151 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Atomic Energy Div., ADLAN-A

152 Commander, Hq. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDHWA

153 Commander, Western Development Division (ARDC) P.O. Box 262, Inglewood, Calif. ATTN: WDSIT, Mr. R. G. Weitz

154-155 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2

156-160 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.

161-162 Director, Air University Library, Maxwell AFB, Ala.

163 Commander, Lowry AFB, Denver, Colorado. ATTN: Dept. of Sp. Wpns. Tng.

164 Commandant, School of Aviation Medicine, USAF, Randolph AFB, Tex. ATTN: Research Secretariat

165 Commander, 1009th Sp. Wpns. Squadron, HQ. USAF, Washington 25, D.C.

166-168 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCOSI

169-170 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.

171 Commander, Air Defense Systems Integration Div., L. G. Hanscom Field, Bedford, Mass. ATTN: SIDE-S

172 Assistant Chief of Staff, Intelligence, HQ. USAFE, APO 633, New York, N.Y. ATTN: Directorate of Air Targets

173 Commander, Alaskan Air Command, APO 942, Seattle, Washington. ATTN: AAOTN

174 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

175 Assistant Secretary of Defense, Research and Engineering, DOD, Washington 25, D.C. ATTN: Tech. Library

176 Executive Secretary, Military Liaison Committee, P.O. Box 1814, Washington 25, D.C.

177 Chairman, Armed Services Explosives Safety Board, DOD, Building T-7, Gravelly Point, Washington 25, D.C.

178 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.

179 Commandant, The Industrial College of The Armed Forces, Ft. McNair, Washington 25, D.C.

180 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary

181-188 Chief, Armed Forces Special Weapons Project, Washington 25, D.C.

189 Commander, Field Command, AFSWP, Sandia Base, Albuquerque, N. Mex.

190 Commander, Field Command, AFSWP, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG

191-195 Commander, Field Command, AFSWP, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT

196 Commander, JTF-7, Arlington Hall Station, Arlington 12, Va.

197 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N.Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

198-200 U.S. Atomic Energy Commission, Technical Reports Library, Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)

201-202 Los Alamos Scientific Laboratory, Report Library, P.O Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman

203-207 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.

208-210 University of California Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. ATTN: Clovis G. Craig

211 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.

212-245 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)